A vertical portfolio approach to procurement

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A Vertical Portfolio Approach To Procurement

Master Thesis

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Eindhoven, June 2015
Abstract

This thesis describes the results of a Supply Chain Finance research project in the pre-shipment environment of Heineken BV. Based on interviews, literature and internal documents three Procurement Models with increasing upstream intervention that Heineken applies worldwide, are identified. By using the Adjusted Cash Conversion Cycle (ACCC) the percentage of financing costs are uncovered in the final product, which can be reduced if Heineken would finance the commodities.

Three quantitative models are developed in order to gain insights into the profits, risks, and contract sizes from Heineken’s perspective and the total supply chain, including the Malt Plant and Farmer. Via Monte Carlo simulation the performance of a business case for the three Procurement Models is tested and via sensitivity analysis the impact of specific parameters on each of the Procurement Models is analyzed. The overall supply chain will always benefit from more involvement by Heineken, because total financing costs in the supply chain can be reduced. However, Heineken’s risks increase by increasing upstream intervention, while profit does not always increase. Therefore Heineken needs to manage its risk appropriately. A potential remedy is by reallocating some of the risks and costs back to suppliers to make a potential business case more interesting for Heineken.

An upstream (vertical) portfolio approach is developed for this research to measure the impact of allocating different weights to each of the Procurement Models. By adopting a mean-variance approach profits and risks for a number of portfolios are calculated. The vertical portfolio approach can significantly increase Heineken’s profit or reduce its risk, compared to a single Procurement Model. In this thesis the concept of the efficient frontier is used, which is defined as the collection of portfolios that will maximize expected profits, for a given level of risk, or equivalently, minimize risks for a specific level of expected return. Heineken does not have ‘one’ single optimal portfolio, but should always select a portfolio of Procurement Models located on the efficient frontier to maximize its performance.

Keywords: Supply Chain Finance, Adjusted Cash Conversion Cycle, Monte Carlo Simulation, Supply Chain Contracting
Problem Statement

Heineken, a global brewing company, currently faces the problem of deciding on a specific Procurement Model (PM), but has no quantitative decision-making tool to substantiate its choice. In general, higher upstream involvement in the supply chain will result in more direct risk for Heineken, but also more control of the supply chain and potential price reductions. Due to Heineken’s global scale, PMs are employed side by side due to economical differences, resilience of the supply chain, etc. Because PMs are used next to each other Heineken already has a portfolio of PMs, however has no quantitative insights in the optimal portfolio. Next to the strategic choice for a PM, on an operational level, Heineken has to decide on yearly purchase quantities (contract sizes). Heineken aims to determine optimal contract sizes to maximize expected profits, facing uncertain demand and dual-sourcing strategy.

The goal of this research is to quantitatively model the three PMs deployed by Heineken, making it possible to compare them. By comparing the three PMs, quantitative insights for Heineken can be attained of differences between the PMs. Based on Heineken’s risk preference, a decision for the optimal allocation between the different PMs will be possible. The quantitative models of each PM will enable Heineken to determine optimal yearly contract sizes, by taking various financial and operational characteristics into account.

Procurement Models

Heineken has operations in more than 70 countries worldwide and procurement for barley and malt is organized differently per region. In broad terms, three distinct PMs with varying upstream intervention have been identified at Heineken.

The Soft-Tolling is most commonly applied throughout the world, mainly in developed regions and areas where barley is not a specialty crop. In this model, Heineken is merely fixing the price of future deliveries, but no active intervention in the upstream supply chain is taking place. The Hard-Tolling is applied in areas where active attention from Heineken is required to stimulate Farmers to crop barley. In this PM ownership during the conversion process is already located at Heineken instead of the Malt Plant and Heineken needs to contract with Farmers and Malt Plants. The Contract Farming model is applied in regions where Farmers are credit constrained and Heineken is forced into assisting the Farmer with financing. In the Contract Farming model it is assumed that Heineken is responsible for delivering and financing the seeds, fertilizers and all variable input costs. Furthermore, Heineken is exposed to various supply chain risks, that were previously allocated to Farmers.
Models & Business Case

For each of the PMs profit functions for all supply chain participants are established. Also a specific timing of events is assumed and an allocation of the risks to either Heineken, Malt Plant or Farmer for the three PMs. Via Monte Carlo simulation insights are obtained in profits and risks, from Heineken’s perspective and the perspective of the entire supply chain, including the Malt Plant and Farmer. This simulation approach allows for quantitative comparison between the three PMs. For a specific business case the performance of the three PMs is tested and the results are shown in table 1. Heineken can achieve the largest expected profits $E[\pi]$ in the Hard-Tolling model, however needs to accept the corresponding increase in standard deviation of the profits $\sigma[\pi]$, the measure for risk, compared to Soft-Tolling. Furthermore, Heineken has to free up Working Capital for financing the inventories.

<table>
<thead>
<tr>
<th>Contract</th>
<th>Soft-Tolling</th>
<th>Hard-Tolling</th>
<th>Contract Farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>q1</td>
<td>10,592</td>
<td>9,809</td>
<td>9,680</td>
</tr>
<tr>
<td>q2</td>
<td>14,750</td>
<td>14,750</td>
<td>14,704</td>
</tr>
<tr>
<td>q3</td>
<td>16,280</td>
<td>16,280</td>
<td>15,869</td>
</tr>
<tr>
<td>Heineken</td>
<td>€3,996,375</td>
<td>€4,027,484</td>
<td>€3,999,945</td>
</tr>
<tr>
<td>Malt Plant</td>
<td>€247,148</td>
<td>€332,721</td>
<td>€332,783</td>
</tr>
<tr>
<td>Farmer</td>
<td>€250,232</td>
<td>€250,232</td>
<td>€318,112</td>
</tr>
</tbody>
</table>

Table 1: Results Business Case

Via sensitivity analysis the impact of various parameters on profits and risks from Heineken’s perspective as well as total supply chain perspective, are investigated. The impact of the spot price of malting barley, quality failures, uncertain demand, and yields are investigated. The total supply chain will always benefit from higher upstream intervention by Heineken. Higher profits can be achieved in the total supply chain, because financing costs are reduced. Furthermore, Heineken is better able to cope with risks due to its relatively larger size, resulting in lower risks from a total supply chain perspective. An important insight for Heineken is that risks will always increase with higher upstream intervention, while Heineken’s profits do not always increase. Therefore, Heineken can possibly reallocate some of the risks or costs back to its suppliers, to make it an overall interesting business case.

Portfolio Approach

Heineken can construct a Procurement Portfolio and assign different weights to each of PMs to search for an optimal portfolio that matches its risk-return preference. Modern Portfolio Theory (MPT) is a financial theory that aims to maximize expected profits, for a given level of risk, or equivalently minimize risk for a specific level of expected profits. Portfolios that match this description are located on the efficient frontier, exemplified by the green line in figure 1. For three different levels of correlation (ranging from low to high) between the PMs,
the mean-variance optimization is performed. On the x-axis risk is shown and on the y-axis profit is represented and Heineken always want to choose portfolios that are as far as possible to the left (with low levels of risk) or upwards (with high levels of profit). We conclude that there is not ‘one’ optimal portfolio for Heineken in terms of expected profits and risks. However, there are many portfolios that are not optimal. Heineken should always construct a portfolio of PMs located on the efficient frontier to maximize its performance.

**Recommendations**

For Heineken three important recommendations are identified:

- **Decision-support tool**: Apply the optimization model for tactical decision-making and improve procurement activities. More specifically, use the optimization model for the PMs to determine optimal yearly contract sizes, taking various financial and operational characteristics into account.

- **Parameterization and Configuration**: All parameters and random variables can be observed in real-life, so Heineken should exert efforts to correctly parameterize the quantitative models. If the input parameters closely match with real-life parameters in the supply chain, Heineken can obtain better insights in performance and make the quantitative models operational. Furthermore, Heineken could configure the model to reallocate risks and costs back to suppliers in consultation with suppliers to create insights in different configurations of supply chains.

- **Strategic management tool**: Apply the insights developed in this thesis to improve and substantiate Heineken’s global replenishment strategy and determine, based on Heineken’s risk preference, if higher upstream intervention if desirable. Furthermore, Heineken should check if the current allocation to different PMs is located on the efficient frontier, otherwise Heineken is not fully reaping the benefits of diversification and its global scale.
Preface

This report is the result of my master thesis project, in partial fulfillment for the degree of Master in Operations Management at Eindhoven University of Technology and in partial fulfillment for the degree of Master in Finance of Tilburg University. I performed the research at Heineken Global Procurement in Zoeterwoude.

First, I would like to thank everyone at Heineken that made my stay enjoyable and very informative. Especially my supervisor Joost van Beem, who has given me all the freedom and support to conduct this research and has contributed in making it a fruitful research effort. Furthermore, my colleagues at Supplier Finance, William Pont, Florian Harder, and Robert Wijers, that were always willing to drink a cup of coffee, even though their agendas were always full. Finally, I would like to thank my colleagues at Raw Materials, Edwin Zuidema and Felipe de Alcantara in particular, that have shared their insights and helped tremendously in my understanding of the barley-malt supply chain.

Next, I would like to thank my university supervisors Bertrand Melenberg and Matthew J. Reindorp. Bertrand, when we first met in december 2014, I had been working on the project for quite some time. Due to your strong analytical skills, you were quickly up to speed. I want to thank you for your valuable comments and concrete feedback on the work, which have been very useful in improving the results. Matthew, this is the second project we embarked upon together and you really taught me what it is like to work in academics. I want to thank you for your perpetual patience in the beginning phase in finding a suitable research project and always freeing up your schedule for our long and weekly discussions. I’m also looking forward in working together again, trying to get the work published in an academic journal.

Furthermore, I would like to thank my family and friends for their continuous support, for motivating me at times when my motivation was nowhere to be found, and cheering me up at times when I was down. Although finishing the thesis was a considerable task for me, I am proud of the final result and you made the journey much more enjoyable. Completion of this thesis marks the end of my life as an ’eternal’ student. However, I’m looking forward to my backpack adventure together with Joren Bozon, my ’thesis buddy’, in South America and the rest of the future to come with good friends and loving family. Vamonos!
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Chapter 1

Introduction

In this thesis the results of a master thesis project are presented, which is related to Supply Chain Finance research beyond Reverse Factoring in the pre-shipment environment. This research was carried out at Heineken Global Procurement (HGP) and its scope is the barley-malt supply chain. By studying three different Procurement Models (PMs) for the barley-malt supply chain with increasing upstream intervention, insights are gained in the risks and returns for Heineken. Although the scope of this research is this specific supply chain, the developed approach can be reapplied to other supply chains.

Supply Chain Finance (SCF) deals with financial arrangements used in collaboration by at least two supply chain partners with the aim of improving the overall financial performance and mitigating the overall risks of the supply chain [Steeman, 2014]. There is a huge potential to achieve benefits by upstream collaboration in the supply chain. Malt is a key ingredient for beer brewing and Heineken must assure delivery of this commodity. Therefore, studying early intervention to increase supply chain performance or to mitigate risks from a supply chain perspective is appropriate. Both the performance of Heineken and the total supply chain, including Heineken’s suppliers, are examined for the three different PMs.

1.1 Problem Statement

Malted barley is one of the key ingredients for Heineken’s beer brewing process. Heineken employs different PMs in regions throughout the world for procurement of barley and malt and the risk-return profiles differs. A short description of the various PMs is provided in table 1.1. Due to Heineken’s global scale, it deploys various PMs side by side. But how does Heineken select the PM in the barley-malt supply chain that is most appropriate in the vastly different business contexts in which it operates?

The barley-malt supply chain is characterized by large inventories present in the supply chain. Seasonality in agriculture results in large inventories, which cannot be reduced by operational techniques. Large inventories lead to high financing costs of working capital that upstream suppliers will eventually include in the selling price. Heineken has a better credit rating than most of its suppliers and is therefore able to obtain cheaper financing rates to lower financing costs of inventories. By leveraging Heineken’s creditworthiness there is a potential to reduce financing costs. Malt represents a large expense for Heineken and reducing input costs and managing the volatility of input prices is an agenda item of Heineken. However, the drawback of reducing financing costs by higher upstream involvement is that
CHAPTER 1. INTRODUCTION

it will result in more risks for Heineken. Financing inventories from one’s upstream suppliers to reduce financing costs in the supply chain, is proposed in a number of academic papers. By leveraging one’s relative strong credit rating, financing costs can be reduced [Randall and Theodore Farris, 2009, Viskari and Kärri, 2012, Gomm, 2010, Hofmann, 2009]. However, none of these authors have developed models to create insights into the risks of shifting or financing these inventories.

In the barley-malt supply chain Heineken has to decide on contract quantity sizes that will maximize expected profits, facing uncertain demand and dual-sourcing options. Heineken can either enter into contracts with suppliers in each PM, or can decide to rely on supply of barley via the open spot market. By committing to pre-determined volumes and pricing in contracts, Heineken is giving up on the opportunity to reap the benefits of a low commodity price of barley. However, if commodity prices rise Heineken’s profit would be negatively impacted if it secures too little and requires supply from the spot market. Furthermore, an extra risk is present due to the uncertainty in demand. If Heineken enters into a contract with suppliers and demand realization is disappointing, Heineken faces penalty costs by having to pay carry-over costs on the quantity not consumed as stated in the contract.

Currently, there is no quantitative decision making tool that quantifies the differences between the PMs, supporting Heineken in choosing for one of the PMs in specific regions and determine the optimal allocation between the different PMs. Furthermore, no quantitative model is employed for determining optimal contract sizes, taking various financial and operational characteristics into account.

This research will address upstream collaboration in the pre-shipment environment financing inventories, giving insights into profits and risks. By quantifying the PMs this enables Heineken to make a trade-off between the different PMs. Furthermore, the quantitative models enable Heineken to determine optimal contract sizes to maximize expected profits allowing it to optimize its barley and malt procurement. Finally, based on Heineken’s risk preference the quantitative models allow Heineken to determine its optimal portfolio of PMs. The problems and aims of this research set out above inhibit significant potential for improvement for Heineken.

<table>
<thead>
<tr>
<th>Procurement Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract Farming</td>
<td>Barley cropped with the help of Heineken financing or knowledge. Malted by either a commercial malt plant or Heineken owned malt plant. Heineken owns the barley during cropping and malting process</td>
</tr>
<tr>
<td>Hard-Tolling</td>
<td>Barley procured by Heineken after harvest and malted by commercial malt plant. Heineken does not incur yield risk, but does incur conversion risks because of ownership during the malting process</td>
</tr>
<tr>
<td>Soft-Tolling</td>
<td>Barley is procured by commercial malt plants and on their balance sheet. Risk Management covers prices via fixed-delivery contracts.</td>
</tr>
<tr>
<td>Spot</td>
<td>Spot purchases of barley in the open market. Prices and volumes are not fixed in advance and depend on current market prices. Availability is not guaranteed (at certain price)</td>
</tr>
</tbody>
</table>

Table 1.1: Procurement Models
CHAPTER 1. INTRODUCTION

1.2 Company Introduction

Heineken is a global brewing company, in possession of over 250 brands. Operations are located in more than 70 countries worldwide and Heineken has a large geographic footprint. Since 60% of total volume from Heineken is coming from developing markets, it is becoming increasingly exposed to these markets. The Heineken brand is the world’s leading international premium beer and has the highest rated beer brand equity. In 2013 consolidated revenue of Heineken summed up to €19.2 billion and beer volume was equal to 178 million hectoliter. Operating profit in 2013 was €2.941 million and the compound annual growth rate (CAGR) of consolidated operating profits the last 5 years was 10.6%, indicating large growth.

Heineken defined 6 business priorities in order to accomplish its future goals. One of the priorities is that Heineken wants to leverage the benefits of its global scale. In September 2010 Heineken initiated a new strategic initiative named Global Business Services (GBS). The GBS organization sits at the heart of Heineken’s strategy to leverage the benefits of its global scale. The GBS initiative is the umbrella for three projects that are distinct, but are linked and interdependent. The Finance Shared Service Center aims to provide centralized transactional finance business services to Heineken Operating Companies (OpCos). Next, there is an Infrastructure organization focused on solutions to formalize data governance and provide data solutions to various Heineken entities. Finally, there is Heineken Global Procurement (HGP) that provides central procurement services to local OpCos by introducing new purchasing models. HGP is responsible for identifying cost savings, perform stakeholder management, setting up framework agreements, maintaining contact with suppliers and conducting negotiations among other things. Supplier Finance (SF) is positioned within HGP responsible to establish a SF-program to create mutual working capital benefits for suppliers and Heineken. In Appendix A a summary of the goals and benefits for HGP is provided. The GBS Program will enable Total Cost Management (TCM), a 3-year €500 million cost saving program. After the first success, a second TCM2 project has started with the same objective.

1.3 Barley-Malt Supply Chain

Heineken has 165 breweries in over 70 countries worldwide that all need malt for brewing beer. Although Heineken is currently centralizing procurement activities, actual physical procurement and delivery for this ingredient is a local activity. Large differences are visible between regions for the procurement of barley and malt. Before the various PMs for barley-malt are explained, a short overview of the supply chain and its workings is provided in this section. In the barley-malt-beer supply chain there are three important participants contributing to the brewing of beer. Main members of the supply chain are Farmers, Malt Plants, and brewers (in our case Heineken). Downstream distribution of beer will be out of scope for this research; only the upstream supply chain from Heineken will be considered. In figure 1.1 a high-level view of the supply chain is provided.
CHAPTER 1. INTRODUCTION

![Supply Chain Diagram]

Figure 1.1: Supply Chain

Farmers are responsible for sowing, cultivating and harvesting the barley, required for beer-brewing activities. Besides brewing, barley also serves as animal feed and as a component of various health foods. Two types of barley exist: Winter barley and Spring barley. Winter barley is planted end of the year and harvested the following Summer. Spring barley is planted in the Spring and harvested the same Summer in August. Western Europe is the largest producer of malting barley, second is the Americas and third is Central Eastern Europe. Cooperatives are large united groups of Farmers, active in Western Europe and perform the function of financing and logistics in the supply chain.

Before brewers can use the barley in the brewing process, the commodity still requires a processing step. Malt Plants are responsible for the process of barley conversion into malt and the process consists of three consecutive steps: steeping, germination and kilning. Malt Plants are specialized in the controlled germination of barley, which is required to realize constant quality malt.

Heineken is the third largest brewer in the world and sources malted barley all over the world. Worldwide 130 million metric tons of barley are produced each year, but only 25 million metric tons is suitable for brewing beer, roughly equal to 20% of total production. Since barley is very voluminous, transportation costs can be a significant part of total cost if barley needed to be shipped across the globe. This can be seen in the global trade of malting barley, which only amounts up to 3.5 million metric tons.

1.4 Research Questions

In order to give clear directions for the project a number of research questions are formulated. These questions are based on the problem statement, literature review, and interviews with Heineken personnel.

1. How is procurement at Heineken for the barley-malt supply chain currently organized?
2. What elements of information are required in order to model pre-shipment finance?
3. What quantitative models can be designed that can help Heineken for operational and strategic decision-making?
4. Should Heineken increase upstream supply chain collaboration?
5. What is an optimal allocation between the various Procurement Models?

In chapter 2 a summary of the literature review related to this research is discussed. The current academic perspective and developments in literature on SCF, Collaborative Working
CHAPTER 1. INTRODUCTION

Capital, Risk Management, and a Portfolio approach to Procurement are presented. This thesis builds upon various elements in Financial and Operations Management literature.

In order to gain insights in Heineken’s procurement strategy and operations, interviews with buyers were conducted. Chapter 3 contains the analysis of the current procurement activities in the barley-malt supply chain with an explanation of the individual PMs. Besides procurement activities, a number of market trends are also discussed.

In chapter 4 a summary of the main risks in the supply chain are provided, which need to be quantified in order to be used for the quantitative models. A breakdown of the costs in the upstream supply chain is discussed and presented in this chapter as well. Finally, calculating the financing costs is performed via the Adjusted Cash Conversion Cycle and explained in section 4.3.

The analytical notation of three different PMs is provided in chapter 5. The models are based on current practice, the design of the supply chain and how the risks are distributed in the supply chain. By applying an analytical notation it is possible to determine optimal contract sizes, based on a specific set of input parameters and supply chain characteristics. In chapter 6 a fictive business case is designed to compare the three models and sensitivity analysis provides insight in the robustness of profits and risks for different supply chain characteristics and differences between the three different PMs.

In chapter 7 the portfolio approach with a mean-variance optimization is discussed, to check the impact of constructing portfolios on profits and risks from Heineken’s perspective. A globally active company as Heineken is able install a diversified portfolio of procurement options, which ultimately should result in increased profits and/or decreased risks. Finally, in chapter 8 the conclusions, the limitations and recommendations for this research are provided that Heineken can employ to improve procurement activities.

1.5 Methodology

In order to answer the research questions, we follow the regulative cycle as defined by Van Strien (1997). The emphasis is on the first part of the regulative cycle, because intervention with the required implementation and evaluation is not feasible within the time span of the project. Since pre-shipment financing is a relatively new topic in research, the project also has an exploratory nature.
CHAPTER 1. INTRODUCTION

(a) Regulative Cycle

(b) Quantitative Research Model

Figure 1.2: Methodological Frameworks applied in Research

The quantitative research model, defined by Mitroff et al (1974) is used as a building structure in this project. The type of research is categorized as empirical research, because the goal is to develop a quantitative model that best fits real-life observations. With the help of the mathematical model, insights can be obtained to enhance decision-making. The following research methods have been used in the project:

**Desk Research:** Recent academic literature related to the topic and internal documentation from Heineken (contracts, market research and best practices) are consulted.

**Interviews:** In order to gain insights in the various PMs, interviews with Heineken staff members are conducted.

**Modelling:** By desk research and interviews relevant variables have been identified with their underlying relationships. A mathematical model in MATLAB is constructed, Monte Carlo simulation provides insights in the returns and risks. Via this method we can quantitatively support recommendations for Heineken.
Chapter 2

Literature Review

Nowadays, the intersection between operations and finance is a growing research domain. Sub-optimization of both areas separately will not yield overall optimal results. In the light of financial supply chain collaboration, the term Supply Chain Finance (SCF) originated to optimize physical and financial flows simultaneously in buyer-supplier relationships. In this section, the highlights of the literature review of van Bergen (2015) are summarized.

2.1 Supply Chain Finance

There are many definitions of Supply Chain Finance, but common denominators are that it seeks to optimize operational and financial flows in the end-to-end supply chain. A high level distinction can be made between post-shipment financing (after invoice release) and pre-shipment financing (before invoice release) [Wuttke et al., 2013]. These two categories will be dealt with separately in the next two paragraphs. Heineken’s better credit rating results in a lower capital cost rate and is able to reduce financing costs in the supply chain. The three levers of SCF are: duration, volume, and costs of capital [Gomm, 2010]. In this thesis mainly the difference between costs of capital between supply chain members is exploited.

Post-shipment:
In the post-shipment financing environment financing is provided based on (approved) invoices. One way of lending is ‘factoring’, where invoices are financed without explicit approval of the buyer by a third-party financier. In the last couple of years ‘reverse factoring’ has gained lots of attention, because financing can be provided on approved invoices from large creditworthy buyers. The approval decreases the risk perception for financiers and creates a win-win situation for suppliers and buyers [Seifert and Seifert, 2011]. Dynamic Discounting is another type of post-shipment financing, in this case funds are provided by the buyer itself and not by a financial institution.

Pre-shipment:
All financing activities that investment-grade buyers undertake before delivery, quality control and invoice release to improve the material flows and reduce costs towards their suppliers can be seen as pre-shipment financing. Purchase Order (PO) financing can be classified as one type of pre-shipment financing and is mathematically described in Lange et al (2012) and Wu et al (2014). The commitment of a creditworthy buyer can lead to an increase in profit for buyer and supplier, but is contingent on characteristics such as differences in
CHAPTER 2. LITERATURE REVIEW

creditworthiness. Inventory financing is also a method to assist an upstream supplier in its working capital needs. Providing funds to purchase raw materials, Work-In-Progress (WIP) inventory or goods in transportation are all types of inventory financing that occur in practice. Shifting or financing inventories has been proposed in many papers to reduce financing costs in the supply chain by leveraging a strong credit rating [Randall and Theodore Farris, 2009, Viskari and Kärrí, 2012, Gomm, 2010, Hofmann, 2009]. However none of these authors have developed models to create insights into the risks of shifting or financing these inventories.

2.2 Collaborative Working Capital Management

Net Working Capital (NWC) has mainly been investigated from the single company perspective. However, there are a number of papers that take a collaborative approach to Working Capital Management (WCM). Hofmann & Kotzab (2010) develop a Supply-Chain-oriented perspective on the Cash to Cash (C2C) cycle in which they show that a network perspective to minimize the C2C cycle performs better than a single company perspective. An individual perspective would optimize the Cash Conversion Cycle (CCC) by minimizing inventories and accounts receivables, while stretching account payables. Hofmann & Kotzab (2010) utilize metrics of the cash conversion cycle (CCC) in their conceptual model for inter-organizational working capital management, which is measured in days. In the Adjusted Cash Conversion Cycle (ACCC) however, the amount of capital that is tied up in the value chain is also taken into account [Viskari and Kärrí, 2012]. This model determines the working capital commitments throughout the entire value chain for a specific product. In order to calculate the reduction in total supply chain financing costs one would apply this model to calculate the height of the reduction.

2.3 Supply Chain Contracting

In a typical supply chain each member tries to optimize its own profit, sometimes at the expense of other members. Optimal performance is achievable if firms would coordinate their actions such that overall supply chain profits would be maximized instead of their own performance. In general, decentralized expected supply chains profits will be lower than centralized expected supply chain profits and coordination will add value to the supply chain. This can be achieved by using contracts that coordinate and align incentives of various members of the supply chain. Many type of contracts are studied, ranging from simple wholesale price contracts, revenue-sharing contracts, buy-back contracts, quantity flexibility contracts to quantity discounts contracts in various supplier-buyer settings. Cachon (2006) provides an excellent overview of supply chain contracting literature.

2.4 Procurement Portfolio

Global supply chains have become more complex in the last decade and buyers are faced with a multitude of choices regarding suppliers, type of contracts and various pricing options. From the buyers perspective, there is a need to develop a clear procurement strategy with a focus on both driving down costs and reducing risks. Segmentation of suppliers [Kraljic, 1983] and applying a portfolio approach to procurement [Martínez-de Albéniz and Simchi-Levi, 2005] are helpful tools in achieving this target. The Procurement Risk Management (PRM) team at
Hewlett-Packard (HP) has developed a mathematical model on the procurement side, that resulted in cumulative cost savings of $425 million in a timespan of six years [Nagali et al., 2008]. By taking a structured-contract-approach to manage risk, HP adapts the procurement quantity via fixed contracts, flexible contracts or spot markets to uncertain demand. For the procurement of commodities, buyers can rely on spot markets to meet their needs. Haskös and Seshadri (2007) provide a review of the growing body of literature on the operations of procurement in the presence of spot markets. Many models have been created that aim to construct an optimal replenishment strategy via spot markets, fixed-delivery contracts or options contracts to maximize expected profit [Seifert et al., 2004, Wu and Kleindorfer, 2005, Martínez-de Albéniz and Simchi-Levi, 2005, Fú et al., 2010, Lee et al., 2014].

### 2.5 Operational Risk Management

Modigliani and Miller (1957) have argued in their seminal paper that corporate financing is irrelevant in the case where capital markets are perfect. However, in reality market imperfections such as information asymmetries, bankruptcy costs, taxes, etc. do occur and makes the source of financing relevant again. These market failures also form good rationales of why companies wish to hedge risk. Combining an operational perspective in financial management is a new area of research and offers interesting prospects by integrating these two (Birge et al, 2007). Companies employ financial derivatives to reduce the exposure to input prices, but how these financial contracts intertwine with procurement is relatively unexplored. Exceptions are Caldentey & Haugh (2009) and Caldentey & Chen (2012). These authors study supply contracts in the face of financial activities, integrating financial and operational perspectives.
Chapter 3

Procurement Activities

Heineken Global Procurement (HGP) is the department within Heineken where this research is conducted. The PMs for barley and malt will be discussed in more detail in section 3.1. In section 3.2 a number of underlying market trends are provided, because these will impact Heineken’s choice for a specific PM.

3.1 Procurement Models

Various methods exist by which Heineken gets the malt delivered to the breweries and in this section these variants are discussed. Three main PMs, subject of discussion, are Soft-Tolling, Hard-Tolling and Contract Farming. Besides the PMs, Heineken can resort to the spot market. Although the spot market offers lower guarantee on availability, it offers more flexibility in terms of quantity and pricing. In figure 3.1 a graphical representation of the three PMs that will clarify the differences on three important characteristics is provided. The main differences are the amount of Heineken’s Net Working Capital (NWC) employed, the risk profile, and the control that Heineken can exert over the supply chain. All characteristics increase moving from Soft-Tolling to Contract Farming.
3.1.1 Soft-Tolling

Stated earlier, malt is a key ingredient and it is important for Heineken to re-assure delivery of this commodity. Besides quality and availability, pricing is important for Heineken because malt represents a large percentage of the cost price. The volatility of commodity prices exposes buyers to price risks. In order to mitigate these risks, large buyers fix prices for future deliveries of input commodities via financial instruments. Because of the lack of a standardized market for barley, Heineken is mainly designated to fixed-price delivery contracts with Malt Plants in the Soft-Tolling model. The forward-looking Risk Management policy dictates what percentage of the exposure Heineken needs to have covered within a certain time frame for the upcoming year(s).

Heineken employs financial instruments, mainly forwards (non-standardized contract between two parties to buy or to sell an asset at a specified future time at a price agreed upon today) to manage price risk. Complex financial derivatives, such as swaps and options, are less commonly exploited at Heineken to manage price risk for barley. The benefit of using forwards, is that Heineken is guaranteed of fixed-price deliveries in the future and doesn’t incur downside risks i.e. a price increase. The disadvantage of forwards is that Heineken have to give up on the upside potential in the case of low commodity prices. Heineken cannot reap the benefits of low commodity prices by using forwards, since pricing is fixed.

3.1.2 Hard-Tolling

The main difference between Soft-Tolling and Hard-Tolling in the barley-malt supply chain, is that ownership during conversion of barley to malt is already placed at Heineken instead of the supplier. Price fixing of future deliveries is still prevalent in the Hard-Tolling model, although Heineken has to fix prices directly with the Farmer instead of with the Malt Plant.
Furthermore, Heineken needs to separately contract with the Farmer on the barley quantity and with the Malt Plant on malting services. The Malt Plant will merely invoice Heineken for their malting fee to convert barley into malt in the Hard-Tolling model. The risk profile differs between the two PMs, because of the exposure to conversion risks and responsibility of Heineken to arrange procurement of barley.

In scholarly literature, Hofmann (2010) defines this concept as 'Natural Hedging', where globally active firms - an Original Equipment Manufacturer (OEM) for instance - can hedge currency and commodity price risks, as well as operational risks by centralizing supply of commodities with their second-tier suppliers. In this scenario, OEMs are exposed to more direct risks, because they can no longer push this risk to upstream suppliers. However, the collaborative approach ensures supply chain wide risk mitigation, possibility of risk sharing through pooling, lower supply chain disruptions and better purchasing conditions due to economies of scale. Another important factor, which is a subject of investigation in this thesis, is reduced working capital costs, because inventories can be financed at lower interest rates.

### 3.1.3 Contract Farming

In the Contract Farming model Heineken takes an even more proactive role and intervenes early on in the supply chain, by supplying the Farmer with its required materials. In many regions in the world Farmers have traditionally been credit constrained due to asymmetric information, lack of financial statements, higher perceived risk of business activities, high transaction costs, concerns on commercial viability, and lack of collateral. Therefore many end-users of agricultural products are forced into financing Farmers to secure commodity origin. This PM is thus mainly deployed to increase security of supply in regions where Farmers are credit constrained. Not all Contract Farming methods are alike, Eaton and Sheperd (2001) identify different types of Contract Farming. The intensity of the contractual arrangements and collaboration vary on three important area’s:

- **Market provision**: where buyer and seller agree on pricing and conditions for future deliveries of the product.

- **Resource provision**: next to the marketing arrangements, commitments from the buyer to supply selected inputs and providing financing or assistance.

- **Management specifications**: growers agree to follow-up on recommended production methods.

Although different types of Contract Farming models are available, in this research an intensive collaboration between Heineken and the Farmers is assumed. Heineken is responsible for delivering and financing the seeds, fertilizers and all variable input costs. Furthermore Heineken is exposed to risks that were previously allocated to Farmers. A detailed explanation of the distribution of risks is provided in chapter 5.

### 3.1.4 Spot

Another procurement option for Heineken is to leave volume open for spot markets. The contract between Heineken and the Malt Plant is not only aimed at fixing prices, contracts are
also used to reserve capacity at Malt Plants for malting services. In some markets Heineken will allocate almost all of its malt requirements to contracts, while in other areas smaller coverage ratios are applied. This is mainly related to the expected future price of malt, security of supply, and malting capacity issues. In areas where large overcapacity prevails and future prices are expected to decrease, Heineken can get malt cheaper from the spot market than by contracting in advance. A number of drivers for leaving volume open for the spot markets are identified:

- Expectation of carry-over volume: volume that is carried along from the previous year and reduces the need for contracting in the year after. Heineken has to pay a ‘penalty’ to suppliers for carry-over volumes.

- Bearish or bullish market spot prices: when Heineken expects that prices will increase, it will allocate smaller volumes to the spot markets and vice versa. If Heineken contracts with suppliers, pricing of future deliveries are always fixed.

- Capacity issues of Malt Plants: if capacity is scarce than Heineken needs to contract more than if Malt Plants run at low capacities and are willing to offer discounts outside of contracts.

- Availability good quality barley: in markets where availability of good quality barley is bad, Heineken will contract more in advance and leave less volume open for the spot market.

- Risk aversion and coverage ratio of barley exposure/needs: security of supply is the starting point for Heineken and they will always try to minimize the risk of not attaining required malt for brewing. Allocating larger amounts to the spot market is riskier, because if harvests are bad and availability low, Heineken cannot rely on contracts.

### 3.2 Market Trends

There are a number of trends in general and some specific to the barley-malt-beer supply chain. In this section a number of market trends are elaborated upon, which have to be taken into account providing Heineken with recommendations on the most promising PM.

- According to data from the OECD, small and medium-sized enterprises (SMEs) face higher interest rates than large companies. Besides this fact, SMEs more often get a ”no” on a loan request. Furthermore, loan conditions for SMEs displayed increased demands for collateral and shortened maturities, which harms the liquidity and ultimately the viability of SMEs. Although interest for SMEs have gone down the interest spread between SMEs and large firms have increased [OECD, 2012]. A larger differential in interest rates favors the adoption of Supply Chain Finance solutions, because an important driver is the credit leverage of the buyer compared to the supplier.

- Another important factor to take into account is the levels of debt of Farmers, because this could lead to financial distress if Farmers are not able to meet their interest and principal payments on outstanding loans. The indebtedness of Farmers differs widely throughout the world, as is discussed shortly in the following section. In the United States, farm debt has risen nearly 5 % annually since 2004, which raises questions
whether U.S. farm operations will remain viable in the future, mainly the younger and smaller farms [Briggeman, 2010]. However, in the EU the picture of debt levels of Farmers and potential issues are different, as Petrick & Kloss (2013) have shown in their research. In general, except for Denmark, all Farmers exhibit low levels of debt and declining interest rates and are less probably to face financial distress in the near future.

- Large traders are actively intervening with their suppliers to control the entire supply chain. If upstream markets become more concentrated, Heineken will have to deal with larger suppliers. On the one hand, this is beneficial because these suppliers could potentially deliver better prices, due to increased efficiency. On the contrary, the bargaining power of Heineken towards suppliers will decline. Furthermore, the difference in creditworthiness could decrease if upstream suppliers are becoming more concentrated and financially more stable due to economies of scale. This will lower potential benefits of upstream collaboration.
Chapter 4

Supply Chain Modelling

In this chapter the elements required to model the quantitative PMs of Heineken, are identified. An important characteristic to take into account is the risks involved in the supply chain. These risks need to be included in the quantitative models as random variables and are explained in this section. The relationship between risks and profitability will become apparent in chapter 5. In section 4.2 the breakdown of costs is provided, because this determines the amount of variable costs that suppliers require Working Capital for. In section 4.3 the Adjusted Cash Conversion Cycle (ACCC) is discussed. The ACCC together with the costs breakdown, provide insights in the amount of financing costs in the final product.

4.1 Supply Chain Risks

First, all the risks present in the supply chain are identified and discussed in this section. It is assumed that Heineken is able to accurately estimate probability density functions of all risk factors and they can be defined as risks and not as uncertainties [Knight, 2012]. The difference between risk and uncertainty is that while discussing risk, the probability distribution is a known factor. In the case of uncertainty one does not know the exact probability distribution, adding an extra layer of uncertainty.

Yield Risks
Agriculture is a risky occupation, because Farmers are confronted with an ever-changing landscape of prices, subsidies and other events that determine the profitability of Farmers [Harwood et al., 1999]. Farmers yields (metric tons of barley per acre) are dependent on weather circumstances and determine the tons of barley that are eventually coming from the fields and are able to be delivered to customers. Yields can drop sharply due to unforeseen conditions, resulting in different profits compared to expected profits, which is a risk that is often borne by Farmers. Farmers can appeal to an Act of God clause in case of these circumstances, which are often incorporated in contracts. The clause excludes Farmers from paying penalties if agreed quantities cannot be delivered.

Demand Risks
Heineken faces uncertainty on the volume of selling beer and is cautious in providing quantity commitments to suppliers. Disappointing demand could result in large inventories of malt for Heineken or paying carry-over penalties to suppliers. On the contrary, if demand suddenly increases, Heineken could be faced with undesirable shortages. Determining optimal contract
sizes is a responsibility of HGP. Although beer markets are expected to grow with 2-3% per year on average for Heineken, deviations do occur and make demand risks appropriate to take into account.

**Quality Risks**
In order to brew consistent quality beer, brewers need malted barley that meets pre-determined specifications. Heineken has standardized specifications and created bandwidths for important evaluation criteria. Examples of specifications are protein levels, moisture levels, and fermentability. Malt Plants should deliver malt according to pre-defined specifications and Heineken has the right to refuse delivery if quality standards are not met. Quality of malt depends heavily on quality of barley and therefore Malt Plants also require the barley that Farmers deliver to meet certain requirements. Because barley is an agricultural product, quality is determined mainly by weather circumstances and skills of Farmers and thus differs per harvest year, region or farmer. If barley does not meet specifications it can be sold as feed barley to livestock farmers, however at a discount compared to malt barley. The same principle applies to malt; other brewers or farmers accept the malt out of Heineken’s specifications at a discounted price.

**Conversion Risks**
Malt Plants are responsible for the conversion process of barley into malt. The conversion factor states how many metric tons of barley are required to make a single metric ton of malt. Due to quality of the barley this conversion factor varies. However, Heineken often agrees upon a fixed conversion factor in contracts. Windfalls or setbacks in the conversion factor (i.e. higher or lower conversion factors) imply that more or lesser barley is required to deliver malt and are for the account of the Malt Plant.

**Price Risks**
Prices of commodities fluctuate over time and affect sellers as well as buyers. In figure 4.1 the price development of the FOB Creil for the last decade is provided. The FOB Creil stems from the price of barley in the area Creil, where a lot of barley is produced under the Incoterm, named Free on Board (FOB). FOB Creil is an important reference price for Heineken in Europe because a lot of barley is sourced from France. Managing price risk is important for all members of the supply chain and they are therefore engaged in risk management activities fixing prices in advance of deliveries. Fixing prices provides downward protection, but forgoes upside potential. Two researchers have indicated that Alberta Barley, which is a reference price used in America, behaves according to a Geometric Brownian Motion [Turvey and Power, 2006]. A Geometric Brownian Motion implies that the price of the commodity satisfies the condition of a random walk with or without a drift. An average price and standard deviation that matches the random walk can thus be applied to model the spot price.
Ownership Risks
Another risk factor to consider is the risk of actually owning the commodity. During storage or transportation damages, loss or theft could occur that have a negative financial impact for the owner. In the barley-malt supply chain due to high inventory levels and many physical flows this represents a significant risk factor. Contracts, insurance and Incoterms are means to mitigate, allocate or share these risks. In this research ownership risks are left out the mathematical analysis. The main argument to leave out ownership risks is that these types of risks can be insured by insurance companies and that they are difficult to explicitly include in the models.

Security of Supply
From Heineken’s perspective it is important to secure the key ingredients for beer brewing. If issues in supply would arise, this will lead to problems in beer production. Heineken needs to create incentives to Farmers and Malt Plants by providing volume-commitments for procurement of the commodities. Security of high-quality barley can be described as the Achilles-heel of the brewing industry; without malting barley, no beer.

4.2 Cost breakdown
In order to make a profit each of the supply chain members needs to procure raw materials and incur production costs. In this section the cost breakdown for the Farmer, Malt Plant and Heineken are discussed separately. Breakdown of the costs is relevant, because applying Hard-Tolling or Contract Farming can reduce the financing costs, which are currently included in the production costs.

Farmer
The Farmer is responsible for growing the crops and needs to procure seeds, fertilizers, and insecticides in advance. These types of costs are categorized as input costs $i_3$ and dependent on the intention of the Farmer to crop a specific amount of malting barley. Besides variable costs, the Farmer is also faced with fixed costs that are described as production costs $c_3$. Labor costs, depreciation, and financing costs, among others, put together the production costs. A focus will be placed on the financing costs, because there is a potential to reduce financing
costs by upstream intervention. In figure 4.2 a simplified example of the cost structure of a farmer is provided under the Soft-Tolling model. The selling price $r_3$ of the Farmer is equal to the sum of the input costs $i_3$, production costs $c_3$, and profit margin $p_3$.

![Figure 4.2: Typical Cost Breakdown Farmer](image)

**Malt Plant**

A Malt Plant is specialized in the controlled germination of cereals, in our case malting barley. There are five stages in the process of converting barley into malt. It begins with the grading of the barley and cleaning, steeping, germination, kilning and eventually the cleaning of the malt and the grading. The conversion factor $K$ is usually between 120 and 130 kg of barley to obtain 100 kg of malt, but it depends on the quality of the grains and the professionalism of the Malt Plant. The most significant variable input cost $i_2$ for malt is barley. The production costs $c_2$ consists of labor, depreciation, financing costs, and other type of production related costs. If the Malt Plant is responsible for carrying seasonal inventories of barley, financing costs of Malt Plants are significant. The selling price $r_2$ is equal to the sum of the input costs $i_2$, production costs $c_2$ and profit $p_2$. A typical costs breakdown under the Soft-Tolling model is provided in figure 4.3. The input costs $i_2$ can be computed by multiplying the selling price of barley from Farmers by the expected conversion factor $K$. In the typical cost breakdown, this is assumed to be 1.25.

![Figure 4.3: Typical Cost Breakdown Malt Plant](image)

**Heineken**

Brewing companies, such as Heineken, require malt in order to brew beer; it is a key ingredient and represents a significant portion of the cost price of beer. Next to malt, hops, water, additional raw materials, transportation costs, and packaging materials are important cost components and classified as variable costs. Overhead costs for brewers consist of depreciation, labor costs, beer taxes, interest and financing costs. For the ease of representation, only malt is considered as variable input costs $i_1$ and the other raw materials are labeled as production costs $c_1$. Malt roughly represents between 5%-10% in the cost prices of beer, but this depends...
on the type of brand, additional use of additives, and advertising costs among others. Figure 4.4 provides the typical cost breakdown of Heineken in the Soft-Tolling model. In the example, it is assumed that with 1 ton of malt Heineken is able to brew 40 hectoliters of beer. The average selling price of 1 hectoliter of beer is set at €100, resulting in a selling price equal to €4,000 for 1 ton of malt. Profit $p_1$ per ton of malt is around 10%, equal to €400.

![Figure 4.4: Typical Cost Breakdown Heineken](image)

### 4.3 Adjusted Cash Conversion Cycle

In this section it is explained how the reduction in input costs for Heineken is calculated by using the Adjusted Cash Conversion Cycle (ACCC), developed by Viskari & Karri (2012). Before explaining this, first a closer look at the definitions of Net Working Capital (NWC) and Cash Conversion Cycle (CCC) is taken. These two concepts are important to understand, before the ACCC is discussed. Working Capital is an important indicator of a company’s financial performance measuring both the operational financial efficiency and short term financial health [Hofmann and Kotzab, 2010].

**Net Working Capital**

The Net Working Capital (NWC) is defined as the sum of all current assets minus the current liabilities, where the term current is defined as a period up to one year. In general, it consists out of three distinct factors, which are accounts receivable (AR), accounts payable (AP) and inventories (INV). Inventories and AR are classified as current assets, while AP are classified as current liabilities. Other definitions of working capital for example might include cash and short-term liabilities. However, for the sake of simplicity only AR, AP, and INV are taken into account. Money tied up in NWC determines the amount of financing a firm needs for daily operations. It indicates whether a company is in good financial health to pay off short-term creditors. Net Working Capital provides insights in the volume of financing needed for a business, but does not indicates the efficiency of a company in converting cash into cash again.

**Cash Conversion Cycle**

The Cash Conversion Cycle (CCC) approaches working capital from a different perspective than NWC; looking more closely at the number of days capital is tied up in inventories, payables and receivables. The CCC follows the natural sequential steps of a production process, where raw materials are converted into finished goods and sold to customers. If suppliers that deliver the raw materials have a payment term, this decreases the amount of working capital required, on the contrary the payment term towards customers increases working capital needs.
CHAPTER 4. SUPPLY CHAIN MODELLING

The CCC consists out of three separate terms. Firstly, the Days Sales Outstanding (DSO) is the number of days that a company takes to receive payments from its customers. Secondly, the Days Inventory Outstanding (DIO) is the sum of the periods that a firm keeps inventory of Raw Materials (RM), Work-in-Progress (WIP) and Finished Goods (FG). Finally, the Days Payables Outstanding (DPO) are the number of days that firms take to pay its suppliers. The formula for the CCC is presented in the following equation and is expressed in number of days.

\[
CCC = DSO + DIO - DPO
\]

The DSO can be calculated by dividing the average accounts receivable and dividing by yearly sales and multiplying by 365 days, because the daily sales are required in order to find the DSO.

\[
DSO = \left( \frac{\text{Accounts Receivables (AR)}}{\text{Yearly Sales}} \right) \times 365
\]

The DIO is found by comparing the inventory levels of Raw Materials, Work-in-Progress, and Finished Goods with daily Cost of Goods Sold (COGS). Because yearly COGS is clearly visible in financial statements, one could use the annual COGS and multiplying by 365 days.

\[
DIO = \left( \frac{\text{Inventories (RM + WIP + FG)}}{\text{Yearly COGS}} \right) \times 365
\]

The DPO is calculated by taking the average amount of accounts payable are weighing them against the daily COGS. Similar to other calculations, yearly COGS needs to be multiplied by 365 days.

\[
DPO = \left( \frac{\text{Accounts Payables (AP)}}{\text{Yearly COGS}} \right) \times 365
\]

In conclusion, there are 5 stages that have an impact on the amount of Working Capital requirements for any company, which are accounts payable (AP), raw materials inventory (RM), work-in-progress inventory (WIP), finished goods inventory (FG) and accounts receivable (AR). The CCC measures how fast a company converts cash into cash again, by following the cash as it is converted into inventories and accounts payable (AP), through sales and accounts receivable (AR), and then back into cash.

**Reduction COGS with the ACCC**

In order to evaluate working capital costs that are committed to a certain product or company, one needs to know both the volume (NWC) and the duration (CCC). Combining volume and duration with the rates at which these volumes are financed, also known as the cost of capital rate, gives an indication of the financing costs present in the end-product. We make use of the concepts of the Working Capital Management Model constructed by Viskarri & Karri (2012). With a collaborative view or benchmarking view, they propose a concrete model named the Adjusted Cash Conversion Cycle (ACCC) creating insights in financing costs caused by working capital in an inter-organizational supply chain.
The ACCC takes into account the volume, duration and the costs of capital to calculate the financing costs. For each of the 5 stages (AP, RM, WIP, FG and AR) the ACCC measures the number of days committed and the weighted average costs compared to the total price. In our calculations the number of days committed are taken into account, however the volume is considered in terms of the amount of NWC employed and not the weighted average costs compared to total price. Thereby, this approach slightly deviates from the approach of Viskarri & Karri (2012).

Suppliers want to remain viable over time and will include incurred costs for Working Capital in their selling price. Eventually, Heineken is thus paying for the financing costs of suppliers. As analyzed in the cost breakdown section, the production costs of the Malt Plant and the Farmer include these financing costs. If Hard-Tolling or Contract Farming are applied, the interest rate applied is based on Heineken’s creditworthiness instead of the suppliers’ interest rates. The reduction in production costs for Malt Plants in the case of Hard-Tolling and Farmers in the case of Contract Farming, is translated into a lower COGS for Heineken.

In order to find the price reduction, one requires the exact Volume of NWC, Duration of NWC and interest rates. Summing up the individual stages’ NWC requirement needs and dividing by 365 provides the height of the NWC on a daily basis. For inventory stages, the average value of the inventory for the number of days committed is used. Concerning accounts receivable the sales is used and multiplied with days committed, which is equal to the payment term. On the procurement side, the payment term towards suppliers is used and multiplied by the average value of COGS. By multiplying the NWC requirements of suppliers with the interest rate $i_s$, the NWC costs can be calculated. The following formula is used:

$$\text{NWC costs} = \frac{D_{\text{AP}}$I_{\text{AP}} + D_{\text{WIP}}$I_{\text{WIP}} + D_{\text{FG}}$I_{\text{FG}} + D_{\text{AR}}$Sales - D_{\text{AR}}$COGS}{365} \times i_s$$

where

- $D_n$ = number of days committed to stage n
- $I_n$ = average inventory value of stage n
- $Sales$ = average value of yearly sales
- $COGS$ = average value of yearly COGS
- $i_s$ = interest rate of Heineken’s suppliers

The amount of financing cost can be expressed as a % of the total sales for the Farmer as well as the Malt Plant. This can be achieved by dividing the financing costs by sales. If one would multiply the percentage financing cost by the selling price $r_2$ of the Malt Plant or the selling price $r_3$ of the Farmer, the potential reduction in input costs for Heineken can be determined.

If Heineken switches from Soft-Tolling to Hard-Tolling or Contract Farming, a reduction in selling price that is at least equal to the % of financing costs is required. The reason is that both the Farmer or the Malt Plant don’t have to finance the commodities in these PMs any more. Since this responsibility is transferred to Heineken, financing costs from suppliers are also transferred to Heineken in Hard-Tolling and Contract Farming, albeit at a lower interest rate.
In order to find the increase in financing costs for Heineken, the interest rates of the suppliers has to be replaced with Heineken’s interest rate $i_H$. No alterations are implemented with regards to the height of inventories and number of days committed in the supply chain. Total NWC requirements will remain the same; they are merely financed at Heineken’s lower rate $i_H$.

$$\text{NWC costs} = \frac{D_{rm}I_{rm} + D_{wip}I_{wip} + D_{fg}I_{fg} + D_{ar}S\text{ales} - D_{ap}S\text{COGS}}{365} \cdot i_H$$

Again, by dividing the financing costs by yearly sales of the Malt Plant or Farmer, the % of the selling price due to financing costs is found. Heineken will incur these financing costs, because Heineken is now responsible for financing the commodities. Multiplication of this % financing costs with the selling price of a Malt Plant or Farmer will give the increased financing costs for Heineken. In general, financing costs are lower but it depends on the difference in creditworthiness between Heineken and the suppliers. Because of the differences in interest rates, the increase in financing costs for Heineken is smaller than the financing costs are for suppliers.

Since financing costs are included in the production costs $c_3$ of the Farmer or the production costs $c_2$ of the Malt Plant, these are reduced under the Hard-Tolling model or Contract Farming model. Heineken’s production cost will increase in the Hard-Tolling or Contract Farming model, compared to Soft-Tolling. In table 4.1 the various production costs for Heineken, Malt Plant and the Farmer are provided. The lower index indicates the position in the supply chain, with Heineken as 1, the Malt Plant second and the Farmer third. The upper index indicates which PM is applied. For Heineken the production costs are different for each of the models. The Malt Plant’s production costs for Hard-Tolling and Contract Farming are the same (therefore the upper index is $hf$). Finally, for the Farmer the production costs under Soft-Tolling and Hard-Tolling are the same (the upper index here is $sh$).

<table>
<thead>
<tr>
<th>Production costs under various Procurement Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_{s1}^1$ production costs Heineken Soft-Tolling</td>
</tr>
<tr>
<td>$c_{h1}^1$ production costs Heineken Hard-Tolling</td>
</tr>
<tr>
<td>$c_{f1}^1$ production costs Heineken Contract Farming</td>
</tr>
<tr>
<td>$c_{s2}^2$ production costs Malt Plant Soft-Tolling</td>
</tr>
<tr>
<td>$c_{hf}^2$ production costs Malt Plant Hard-Tolling &amp; Contract Farming</td>
</tr>
<tr>
<td>$c_{sh}^3$ production costs Farmer Soft-Tolling &amp; Hard-Tolling</td>
</tr>
<tr>
<td>$c_{f1}^3$ production costs Farmer Contract Farming</td>
</tr>
</tbody>
</table>

Table 4.1: Production costs under various Procurement Models
Chapter 5

Quantitative Analysis of Procurement Models

In this chapter in section 5.1 the general introduction to the PMs is provided. Next, input parameters and decision variables as well as the assumptions and a few important notes are discussed. In section 5.2 the Soft-Tolling model formulation will be given and an explanation on the division of risks. In section 5.3 and 5.4 the Hard-Tolling and Contract Farming model will be explained, respectively. For each of the models a specific sequence of events is assumed, how the model is solved, the distributions of risks, and the profit functions for each of the supply chain participants is provided.

5.1 General introduction Procurement Models

The goal of the development of PMs is to quantitatively support Heineken’s decision between the different PMs. A quantitative approach is helpful in analyzing several scenarios and obtain insights in relevant parameters that affect Heineken’s choice. Within a PM each party optimizes its expected profit, by determining optimal quantities to either put in contracts or for production decisions. The model formulation is defined as an optimization problem.

The sequence of events in the supply chain and the type of PM determines how each of the supply chain members chooses its contract sizes. For a given set of input parameters, the three separate PMs can be solved and the optimal contracting decisions are determined.

In order to compare results of the three different PMs, a uniform way of measuring results is required. Because all models use the same input parameters, expected profits as well as standard deviation of the profits can be compared. In the upcoming sections the profit functions for all parties in each PM are developed. Heineken has a profit function in the Soft-Tolling model, where it is able to decide on the contract size of malt \( q_1 \) between Heineken and the Malt Plant. The profit function, dependent on the realization of random variables, is denoted as:

\[
\pi_{ST}^H(q_1)
\]

The expectation of the profit is taken and maximized, with respect to the decision variable at stake. To provide the reader with an example, Heineken’s profit function maximization in the Soft-Tolling model is provided in the equation below. However, each of the supply chain participants in all PMs will always maximize profits with respect to their decision variables.
Since firms are considered risk-neutral in the quantitative models, they will always maximize expected profits. This risk-neutrality assumption will result in Heineken’s optimal contract size \( q_1^* \), for a specific set of input parameters.

\[
q_1^* = \arg\max_{q_1} E[\pi_{STH}(q_1)]
\]

However, although firms are risk-neutral, not only the expectations of the profit are considered. The corresponding risks of maximum profits are also required to quantitatively compare the three different PMs. In order to measure riskiness, the standard deviation of the maximum expected profit is taken.

\[
\sigma_{STH} = \sqrt{\text{VAR}[\pi_{STH}(q_1^*)]}
\]

Heineken is interested in higher profits, however if risks increase Heineken needs to make a trade-off between expected profits and standard deviation of the profits. Heineken can apply a mean-variance approach to assist in its choice for one of the PMs. Besides profits and risks, an extra consideration on Heineken’s part is the amount of Working Capital that is required for the Hard-Tolling and Contract Farming. This is not explicitly included in the quantitative models, however the differences in production costs between the three models are based on leveraging Heineken’s creditworthiness to reduce financing cost. The increase in financing costs is factored in the models, however the amount of Working Capital Heineken has to free up is not explicitly considered.

As is explained later in more detail, three decision variables are present in the quantitative models. The first decision variable is \( q_1 \), which is the size of the contract between Heineken and the Malt Plant. The second decision variable, the contract size of barley \( q_2 \) is agreed upon between the Malt Plant and the Farmer in the Soft-Tolling model. Finally, the cropping decision of the Farmer is \( q_3 \), which determines the amount of seeds that are put into the ground.

The contract decision \( q_1 \) can be maximized without taking other decision variables into account and is thus optimal irrespective of \( q_2 \) and \( q_3 \). This is related to the availability of a spot market, where Heineken can always resort to for their needs of barley. Upstream quantity decisions can be excluded in the optimization of Heineken’s profit in the Soft-Tolling model.

However, this is not the case for \( q_2 \) and \( q_3 \), under our quantitative model set-up. There is a dependency, which requires a inductive method of finding equilibrium profits, given a set of input parameters. Since the Malt Plant decides first in our Soft-Tolling model, it act as a leader in determining an optimal barley contract size \( q_2 \), however taking the response of the Farmer into account. Because no information asymmetries are present in the quantitative models, via backward induction the Malt Plant can determine the Farmer’s response for each \( q_2 \) decision. For a specific \( q_2 \) decision, an optimal \( q_3^* \) response of the Farmer exists and the Malt Plant can choose from a set of \( q_3^*(q_2) \) decisions. Because Malt Plants can ex-ante predict the Farmer’s response, it is able to determine an optimal contract size \( q_2^* \) that maximizes their profit.

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A Vertical Portfolio Approach To Procurement
CHAPTER 5. QUANTITATIVE ANALYSIS OF PROCUREMENT MODELS

5.1.1 Assumptions and important notes

1. No lost sales
   Because of the presence of the spot market, Heineken will never lose demand for beer due to the absence of malt or capacity issues at Malt Plants. The aim of this research from Heineken’s point of view is to find optimal contract sizes minimizing the costs for purchasing. The assumption for not losing demand of beer is reinforced by the fact that if no good-quality barley is available from the spot market, Heineken can resort to lower quality barley. Summarizing, Heineken faces a cost-minimizing problem, because Heineken never loses demand due to the unavailability of malt or capacity issues.

2. One-period model & Farmer, Malt Plant and Heineken do not act as traders
   The model constructed is a one-period model, inventories cannot be carried over to the next period. Disadvantages of one-period model is that inventories at end of the period need to be salvaged against lower price, while in reality they can be reused in the next year. However if we would set the depreciation in value equal to the costs for storing the commodities, the profits of the one-period model will be a good approximation of a multi-period model. Also if supply chain members would act as traders, they would be able to sell remaining inventory to the spot market instead of writing off the commodities. We assume they do not act as traders in our models.

3. Single item model
   In our models only a single commodity in the upstream supply chain is investigated. In reality, Farmers can choose from a multitude of crops to grow. This creates an issue in the quantitative model, because Farmers will always maximize cropping decision, as long as expected profits are above the expected costs. To cope with this, a decreasing price for each ton of barley sold outside the contract is implemented. This ensures that an analysis on the farmer’s decision adds value. Because supply chain members in the models do not act as traders, this assumption of a decreasing price is plausible and coherent.

4. Quality pass-fail (1-0) mechanism
   Quality is an important factor in this supply chain and quality of barley and malt depends on many characteristics. In the models it is assumed that if quality of barley and malt does not meet specifications, it will be rejected for sale. The commodities will be salvaged on other markets and represent a value, albeit lower than the selling price of the barley and malt that did meet specifications. When barley does not meet quality specifications, Farmers use the Act of God clause to get out of penalties, however Malt Plants have to source barley from the spot market at a higher price and process the barley again. Farmers, Malt Plants or Heineken will incur a loss whenever quality failures arise.

5. Single-party-multi-echelon supply chain
   There is only 1 Farmer, 1 Malt Plant and 1 Brewer (in our case Heineken) present in the supply chain. The conclusions that are drawn for the single-party-multi-echelon supply chain are relevant for the multi-party-multi-echelon supply chain, because a single Farmer can be regarded as a collection of Farmers.

6. Sequence of events is representative for real-life
In order to analyze optimal decisions, a specific timeline of events is assumed for each of the PMs. A different sequence of events will alter the solution space and optimal decisions significantly. Since time is not explicitly incorporated in the model, it is not possible to account for the time value of money.

7. **Uncorrelated and normally distributed random variables**
   Although random variables could be correlated to each other, it is assumed that no correlations among individual random variables are present. For example, spot prices and yields could be negatively correlated in real-life, however it is assumed that correlations for small business cases are minimal and can be disregarded. Another way to approach the absence of correlations, is that the volume of Heineken does not impact the overall spot market price and therefore this relationship can be ignored. Furthermore, it is assumed that random variables are normally distributed in the models, although empirically fitting distributions on actual data will make the model more applicable for Heineken.

8. **Forced Compliance**
   Another important aspect is that suppliers and Heineken are forced to execute the terms of the contract, even if this results in negative profits. In Supply Chain Contracting literature this is dubbed as 'Forced Compliance' contracts, where supply chain participants cannot deviate from contract terms.

9. **No information asymmetries**
   In practice each firm possesses its own private information. In the quantitative models however, it is assumed that no information asymmetries are present. Heineken, the Malt Plant and the Farmer provide full disclosure of all relevant information.

10. **Variable vs. Fixed costs**
    For the Farmer all of his production costs are assumed to be fixed, because of the nature of the Farmer’s occupation. On the other hand, for the Malt Plant and Heineken production costs are variable and can be adapted to actual demand realization. Although this is a simplification from reality, this can be relaxed in further studies.
5.1.2 Input parameters and decision variables

In table 5.1 all the relevant input parameters, the random variables and three decision variables are presented. For each of the variables the symbol, a short explanation, the units in which it is depicted, and the range, if applicable, are provided.

The difference between the input price in contract \( i_1 \) and the input price out contract \( O_1 \) is related to the uncertain spot price \( S \). In \( O_1 \), the price of barley that Heineken requires is variable, while the price of barley in \( i_1 \) is fixed.

As explained in the assumptions, because a single item model is studied, the price of barley for each additional ton sold outside the contract \( q_2 \) decreases. The input parameter, discount excess malting barley \( d \), determines the slope of this decreasing price. Higher levels of \( d \) will delay the decline of the price decrease.

The manner in which the contract between Heineken and the Malt Plant is structured, results in underage and overage costs. The parameter penalty costs \( u \) determines the fine that Heineken pays to the Malt Plant for each ton when demand realization \( X \) is lower than the contract size \( q_1 \). On the contrary, when demand realization \( X \) is higher than the contract size \( q_1 \), Heineken has to pay the Malt Plant a malting premium \( e \) for each ton of malt.

The Malt Plant has two different selling prices in the Soft-Tolling model, namely in the contract \( r_2 \) and outside the contract \( R_2 \). The difference between the two selling prices is that \( R_2 \) is based on the random spot price \( S \), while \( r_2 \) is based on the contracted price of barley \( i_2 \) with the Farmer. As long as demand realization \( X \) is below the contract size \( q_1 \), the selling price in contract \( r_2 \) applies. But as \( X > q_1 \) the Malt Plant will charge Heineken \( R_2 \).

In section 4.3 the various production costs for Heineken, Malt Plant and the Farmer were discussed. Because Heineken will take ownership of the commodities in the Hard-Tolling and Contract Farming model, production costs will increase for Heineken due to an increase in financing costs \( (c_1^f > c_1^h) \). For both the Malt Plant and Farmer the production costs will decrease with more upstream intervention. For the Malt Plant this implies that production costs for Soft-Tolling will be larger than Hard-Tolling or Contract Farming \( (c_2^s > c_2^{hf}) \). The Farmer will only have smaller production costs in Contract Farming, while the production costs for Hard-Tolling and Soft-Tolling are the same \( (c_3^h = c_3^f) \).
CHAPTER 5. QUANTITATIVE ANALYSIS OF PROCUREMENT MODELS

List of variables

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_1$</td>
<td>input price in contract Heineken</td>
</tr>
<tr>
<td>$O_1$</td>
<td>input price out contract Heineken</td>
</tr>
<tr>
<td>$c^s_1$</td>
<td>production costs Heineken Soft-Tolling</td>
</tr>
<tr>
<td>$c^h_1$</td>
<td>production costs Heineken Hard-Tolling</td>
</tr>
<tr>
<td>$c^f_1$</td>
<td>production costs Heineken Contract Farming</td>
</tr>
<tr>
<td>$p_1$</td>
<td>profit Heineken per ton of malt</td>
</tr>
<tr>
<td>$r_1$</td>
<td>retail selling price Heineken $(i_1 + c_1 + p_1)$</td>
</tr>
<tr>
<td>$i_2$</td>
<td>input price Malt Plant</td>
</tr>
<tr>
<td>$c^s_2$</td>
<td>production costs Malt Plant Soft-Tolling</td>
</tr>
<tr>
<td>$c^h_2$</td>
<td>production costs Malt Plant Hard-Tolling &amp; Contract Farming</td>
</tr>
<tr>
<td>$p_2$</td>
<td>profit Malt Plant per ton of malt</td>
</tr>
<tr>
<td>$r_2$</td>
<td>retail selling price Malt Plant in contract $(i_2E[K] + c_2 + p_2)$</td>
</tr>
<tr>
<td>$R_2$</td>
<td>retail selling price Malt Plant out contract $(SE[K] + c_2 + p_2)$</td>
</tr>
<tr>
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<td>input price Farmer</td>
</tr>
<tr>
<td>$c^h_3$</td>
<td>production costs Farmer Soft-Tolling &amp; Hard-Tolling</td>
</tr>
<tr>
<td>$c^f_3$</td>
<td>production costs Farmer Contract Farming</td>
</tr>
<tr>
<td>$p_3$</td>
<td>profit Farmer per ton of barley</td>
</tr>
<tr>
<td>$r_3$</td>
<td>retail selling price Farmer $(i_3 + c_3 + m_3)$</td>
</tr>
<tr>
<td>$d$</td>
<td>discount excess malting barley Farmer</td>
</tr>
<tr>
<td>$u$</td>
<td>punishment penalty costs by Heineken to Malt Plant per ton of malt</td>
</tr>
<tr>
<td>$e$</td>
<td>malting premium costs Malt Plant per ton of malt</td>
</tr>
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</table>

Random Variables

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<thead>
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<th></th>
<th>Units</th>
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<tr>
<td>$B^*$</td>
<td>Barley Failure</td>
<td>%</td>
</tr>
<tr>
<td>$M$</td>
<td>Malt Failure</td>
<td>%</td>
</tr>
<tr>
<td>$K$</td>
<td>Conversion Factor Barley to Malt</td>
<td>-</td>
</tr>
<tr>
<td>$F$</td>
<td>Feed Price</td>
<td>€</td>
</tr>
<tr>
<td>$S$</td>
<td>Spot Price</td>
<td>€</td>
</tr>
<tr>
<td>$T$</td>
<td>Malt Out Spec Price</td>
<td>€</td>
</tr>
<tr>
<td>$W$</td>
<td>Delivery Capability Farmer</td>
<td>tons</td>
</tr>
<tr>
<td>$X$</td>
<td>Malt Demand Heineken</td>
<td>tons</td>
</tr>
<tr>
<td>$Y$</td>
<td>Yield Farmer</td>
<td>tons</td>
</tr>
<tr>
<td>$Z$</td>
<td>Barley Demand Malt Plant</td>
<td>tons</td>
</tr>
</tbody>
</table>

Decision Variables

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<th>Range</th>
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<tbody>
<tr>
<td>$q_1$</td>
<td>Contract decision malt quantity</td>
<td>tons</td>
</tr>
<tr>
<td>$q_2$</td>
<td>Contract decision barley quantity</td>
<td>tons</td>
</tr>
<tr>
<td>$q_3$</td>
<td>Contract decision seeds quantity</td>
<td>tons</td>
</tr>
</tbody>
</table>

* $B \sim f_B$, which is applicable to all random variables

Table 5.1: List of Variables

A Vertical Portfolio Approach To Procurement
5.2 Soft-Tolling

In this Soft-Tolling section first the sequence of events is discussed, because this affects the way the model will be solved, which will be discussed hereafter. Next, the risk allocations for the Soft-Tolling model are discussed and how the goods flow in the supply chain is presented graphically. This section will close with an analytical representation of the profit functions of Heineken, the Malt Plant and the Farmer respectively.

Sequence of Events

In figure 5.1 the events in the Soft-Tolling model are summarized. At $t = 0$ all parties observe the distributions of random variables that affect them and fixed contract prices. Between $t = 0$ until $t = 1$ Heineken, the Malt Plant and the Farmer can decide on their contract size. Heineken makes a decision for the malt quantity contract size $q_1$. The Malt Plant chooses a barley quantity contract size $q_2$ that will provide the barley to meet the barley demand $Z$, which is dependent on malt demand $X$. The Farmer decides on a cropping quantity $q_3$ that will determine the mean of the yield $Y$. At $t = 1$ all quantities and prices are fixed and demand realization can begin.

From $t = 1$ until $t = 2$ demand $X$ is realized and the Farmer delivers the minimum of $q_2$ and the delivery capacity $W$. The Malt Plant receives this amount from the Farmer and orders the remaining required barley quantity ($Z - \min(q_2, W)$) to meet the malt demand $X$ for Heineken from the spot market at spot price $S$. Because the assumption is that spot markets have unlimited availability, the Malt Plant can always satisfy Heineken’s demand. Prices for malt up to $q_1$ are fixed, but deliveries above $q_1$ are not fixed on pricing. They depend on the Spot price of barley $S$ and Heineken thus has to pay more or less for these volumes if spot prices are higher or lower respectively. At $t = 2$ demand is realized and all parties realized their profits and costs.

Model Solving

In the Soft-Tolling model no coordination between the different members is taking place to jointly determine the optimal $q_1^*$, $q_2^*$, and $q_3^*$. The optimal contract size for barley $q_2^*$ and cropping decision $q_3^*$ can be determined, similar to Heineken’s optimal profit for $q_1^*$. In this decentralized model three self-profit maximizing firms are present and Heineken acts as the leader because it offers the first contract $q_1$ to the Malt Plant. Backward induction will provide the optimal contract sizes for the Malt Plant $q_2^*$ and Farmer $q_3^*$, contingent on

![Figure 5.1: Timeline of Events Model 1 Soft-Tolling](image-url)
Heineken’s choice for $q_1^*$, in order to find equilibrium profits. This was explained in more detail in section 5.1.

<table>
<thead>
<tr>
<th>Type of Risk</th>
<th>Farmer</th>
<th>Malt Plant</th>
<th>Heineken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand uncertainty</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Conversion rate</td>
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<td>Yield risk</td>
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<td>X</td>
<td></td>
</tr>
<tr>
<td>Price malt out-spec</td>
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<td></td>
</tr>
<tr>
<td>Price spot feed barley</td>
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<td>X</td>
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<td>Price spot malt barley</td>
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<tr>
<td>Quality failure barley</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Quality failure malt</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2: Risk allocation for Soft-Tolling

**Risk Allocation**

Table 5.2 displays how the risks are divided among the members in the Soft-Tolling model. Because Heineken has the possibility to order less than the contract size $q_1$ at a penalty cost, some of the demand risk is shifted to Malt Plants. Heineken contracts with Malt Plants on a fixed conversion factor $K$ for converting barley into malt, so the risk is allocated to Malt Plants. The Farmer delivers to the Malt Plant the barley up to the contract size $q_2$, but if delivery capacity $W$ is lower, less barley is supplied. The Act of God clause in contracts between Farmers and Malt Plant indemnifies the Farmers from penalties when the contracted quantity $q_2$ is not delivered. Some of the yield risks $Y$ of Farmers are shifted to Malt Plants. If the quality of the malt is not according to specifications, Heineken has the right to refuse the delivery. Malt plants thus have to sell the rejected malt to other brewers or alternative markets.

In our model the Farmer as well as the Malt Plant cannot act as traders and at the end of the period they have to salvage inventory of barley at uncertain feed prices $F$. Also if barley fails the quality inspection, Farmers can sell the commodity, intended to be sold as malting barley, as feed barley to other farmers. If Heineken leaves volume open for the spot market or demand $X$ increases above $q_1$, Heineken will instruct the Malt Plant to get the barley from the spot market at a random spot price $S$, making Heineken subject to price risk of malting barley. A graphical representation of the events and relations among the supply chain participants is provided in figure 5.2.
5.2.1 Profit functions Soft-Tolling

In this section the profit functions for all parties in the Soft-Tolling model are presented. Heineken’s profit function will be discussed first, because it can initiate the first contract. Secondly, the profit function of the Malt Plant and finally the profit function of the Farmer are provided. However in order to proceed with the analysis of profit functions, first an explanation is required of the Farmers yield $Y$, the Delivery Capability of the Farmer $W$ and the Barley Demand of the Malt Plant $Z$.

**Yield**

The yield of the Farmer is defined by $Y$ (total amount of barley from the field) and is a random variable because weather circumstances influence the ultimate output from the fields. At the beginning of the season the Farmer chooses a specific cropping decision, which is equal to $q_3$ and is the mean of the yield ($q_3 = \mu = E[Y]$). The variance of the yield $Y$ is equal to a percentage, defined as $\lambda$, of the $q_3$ decision.

$$Y = q_3 + \lambda q_3 \epsilon$$

where

$$E(\epsilon) = 0$$

$$Var(\epsilon) = 1$$

**Delivery Capability**

The delivery capability of the Farmer $W$ is a random variable that depends on two factors. The yield of the farmer $Y$, together with the barley failure $B$ determines the ultimate delivery capability $W$ of the Farmer. A low yield $Y$ or a high quality failure percentage $B$ will negatively impact the delivery capability $W$ of the Farmer. The relationship between $W$, $Y$, and $B$ is provided in the equation below. The ultimate delivery capability depends on the
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$q_3$ decision, because yield is part of the equation. Only if delivery capabilities of the Farmer are larger than the contract size $q_2$ between the Farmer and the Malt Plant $W > q_2$, will the Farmer be able to deliver the contracted amount. Actual delivery of the Farmer is equal to the minimum of the delivery capability $W$ and the contract size $q_2$, i.e. $\min(q_2, W)$.

$W = Y(1 - B)$

Barley Demand
Finally, we will discuss the barley demand of the Malt Plant, $Z$, which is influenced by three random variables. These random variables are the demand for malt $X$, the malt failure $M$ and the conversion factor $K$. All random variables will positively impact the barley demand $Z$, meaning that a higher demand for malt $X$, higher malt quality failure $M$, or a higher conversion factor $K$ will result in a larger demand for barley $Z$. The relationship between $Z$, $X$, $M$, and $K$ is provided in the equation below. In the Soft-Tolling model, the Malt Plant has to resort to the spot market if actual delivery from the Farmer $\min(q_2, W)$ is lower than the demand for barley $Z$. We will assume that malt failures $M$ or conversion factors $K$ between spot market and contracted transactions do not differ.

$$Z = X(1 + M)K$$

Heineken
In the Soft-Tolling model Heineken initiates the contract with the Malt Plant. The size of the malting quantity contract was defined as $q_1$, which is the decision variable for Heineken and Heineken’s profit is dependent on $q_1$. Because we have assumed spot markets have unlimited availability and Malt Plants do not face capacity issues, Heineken never loses demand for beer. If demand for malt $X$ turns out to be higher than the contract size $q_1$, Heineken resorts to the spot market, by instructing the Malt Plant to procure the barley, for barley requirements $Z$ to meet demand $X$ for malt. The revenue function is thus equal to the realized demand $X$ multiplied by the retail selling price $r_1$.

$$\text{Revenues}_{ST}^{H} = Xr_1$$

However, the cost function of Heineken depends upon the difference between $q_1$ and realized demand $X$. It consists of two cases that have their own cost function. In the first case when $q_1 > X$ applies, Heineken can procure all the required malt for the contracted price $i_1$. Production costs of Heineken are equal to $c_1^i$ and the costs are simply found by multiplying $i_1 + c_1^i$ by realized demand $X$. If $q_1 > X$ applies, Heineken has to pay a penalty costs $u$ to the Malt Plant for the quantity not purchased up to $q_1$. These two terms compose Heineken’s cost function if $q_1 > X$.

The second case is $q_1 < X$ and behaves differently than $q_1 > X$. In the second case Heineken procures at least the $q_1$ amount from the Malt Plant at $i_1$ and incurs $c_1^i$ of production costs to brew beer. For the amount that $X > q_1$, Heineken will instruct the Malt Plant to get the barley from the spot market. Concerning production costs $c_1^i$, these remain the same for Heineken to brew beer. The input cost for Heineken if $X > q_1$ however is now equal to $O_1$, which is the price of malt where the barley is sourced from the spot market and converted into malt by the Malt Plant. This is a random variable and depends upon the spot price $S$.
of barley instead of the input price of barley in the contract $i_2$. The total cost function is provided in the equation below.

\[
\text{Costs}_{ST}^{H} = \begin{cases} 
(i_1 + c_1^i)X + (q_1 - X)u, & \text{if } q_1 > X. \\
(i_1 + c_1^i)q_1 + (O_1 + c_1^i)(X - q_1), & \text{if } q_1 < X.
\end{cases}
\]

The profit function of Heineken can be found by subtracting costs from revenues and is given in the equation below. Heineken can maximize its profit function with respect to $q_1$ and parameters relevant to Heineken’s profit in the Soft-Tolling model.

\[
\pi_{ST}^{H}(q_1; \ldots) = \text{Revenues}_{ST}^{H} - \text{Costs}_{ST}^{H}
\]

**Malt Plant**

The Malt Plant is faced with Heineken’s decision to maximize profits and the corresponding choice for $q_1^*$. It will respond by choosing a $q_2^*$ that provides him with the highest expected profit. However, as we stated earlier the optimal $q_2$ is dependent on $q_3$. The Malt Plant has to take into account the Farmer’s reaction for a specific contract size $q_2$. Since the Malt Plant can decide first and because of the lack of information asymmetry, the Malt Plant knows the Farmer’s response of $q_3$ for each contract size $q_2$. Another underlying assumption is that firms are risk-neutral and will always maximize expected profit.

The profit function of the Malt Plant is somewhat more complex than Heineken’s profit function due to the conversion of barley into malt. First we will look into the cost function of the Malt Plant and after that we will discuss the revenue function. The random variables $W$, $Z$, and $q_2$ need to be evaluated against each other. We have defined six potential cases that are of interest for the cost function of the Malt Plant. In figure 5.3 a graphical representation of the various cases is given, which we will elaborate upon further in this section.

All the terms contain the similar term $X(1 + M)c_2^i$, therefore this will be explained first for all regions. Demand for malt $X$, together with the malt failure percentage $M$, needs to be converted from barley into malt ($X(1 + M)$). The costs for converting a ton of malt is $c_2^i$, and needs to be multiplied by the amount $X(1 + M)$ that requires malting. This cost represents the production costs for the Malt Plant.
Cases 1 and 2 behave similarly, because it doesn’t matter if the \( q_2 \) decision is larger than or smaller than the barley demand \( Z \) if the delivery capacity of the Farmer is smaller than both of them. If the delivery capacity is lowest of the three variables the Malt Plant will procure the available quantity \( W \) at a costs of \( i_2 \), explaining the first term in the cost function. Due to the Act of God clause in the contract between the Malt Plant and the Farmer, no penalty payments will take place. The second term \((Z - W)S\) represents the costs for procuring \( Z - W \) tons of barley at a random spot price \( S \).

The third and fourth case are also similar, because the \( q_2 \) is smaller than both the delivery capacity \( W \) and the barley demand \( Z \). Because of the way the contract between the Malt Plant and the Farmer is structured, the Malt Plant will only receive \( q_2 \) even if delivery capacity \( W \) is larger. Due to a higher spot price \( S \) the Farmer can earn more by selling the extra barley to the spot market instead of to the Malt Plant. The amount that the Malt Plant gets delivered from the Farmer is thus equal to the contract size \( q_2 \) at a cost of \( i_2 \), explaining the first term. The second term is equal to the difference between the contract size \( q_2 \) and the barley demand \( Z \), because if \( Z \) is larger than \( q_2 \) the Malt Plant needs to procure the difference from the spot market at spot price \( S \).

The fifth case is where the barley demand \( Z \) is smallest, the delivery capacity \( W \) is second smallest and the contract size \( q_2 \) is the largest of the three. If this case is applicable the Malt Plant will receive a delivery from the Farmer equal to the capacity \( W \) at a cost of \( i_2 \). However, since the barley demand \( Z \) is smaller than the barley delivered \( W \) to the Malt Plant, the Malt Plant needs to salvage the difference for the feed price \( F \). The amount that needs to be salvaged is equal to difference between \( Z \) and \( W \), which explains the last term. Although this is a cost function of the Malt Plant, this term will become negative and represents a revenue stream.

The last case is where the barley demand \( Z \) is still smallest, however the delivery capacity \( W \) is now larger than the contract size \( q_2 \). The Malt Plant will thus receive a delivery from the Farmer equal to \( q_2 \) at a cost of \( i_2 \) per ton of barley. Also, since the barley delivered \( q_2 \) is larger than the actual demand for barley \( Z \), the Malt Plant will salvage the difference for the
feed price $F$. Similar to the fifth case, the last term will also represent a revenue stream.

$$Costs_{MP}^{ST} = \begin{cases} 
W_2 + (Z - W)S + X(1 + M)c_2, & \text{if } q_2 > Z > W. \\
W_2 + (Z - W)S + X(1 + M)c_2, & \text{if } Z > q_2 > W. \\
q_2 + (Z - q_2)S + X(1 + M)c_2, & \text{if } Z > W > q_2. \\
q_2 + (Z - q_2)S + X(1 + M)c_2, & \text{if } W > Z > q_2. \\
W_2 + (Z - W)F + X(1 + M)c_2, & \text{if } q_2 > W > Z. \\
q_2 + (Z - q_2)F + X(1 + M)c_2, & \text{if } W > q_2 > Z.
\end{cases}$$

The revenue function of the Malt Plant consists of two cases, because the malting quantity demand $X$ can either be higher or lower than $q_1$. When $q_1 > X$, the revenue function consists of three terms. The first term is the retail price multiplied by the actual malt demand $r_2X$. The $(q_1 - X)$ is the amount that Heineken needs to pay a penalty costs of $c$ towards the Malt Plant. Finally, the malt that did not meet specifications, of which the amount is equal to $XM$ can be sold to alternatives, such as Farmers or other brewers. Malt Plants will accept a lower selling price for the malt that did not meet specifications, and this selling price is equal to $T$. Total revenue from malt out of specification is equal to $XMT$.

If realized demand is larger than the contract size $q_1 < X$, a different revenue function applies. First of all, the Malt Plant will sell a quantity of $q_1$ to Heineken at a price of $r_2$, explaining the first term $r_2q_1$. When realized demand is larger than the contract size $q_1 < X$, the quantity sold outside the contract is $X - q_1$. Pricing is different, because it depends on the spot price $S$ instead of the contract price of barley between the Farmer and the Malt Plant. Therefore the quantity above the contract $X - q_1$ is multiplied with the selling price out the contract $R_2$. Finally, the malt that did not meet specifications is salvaged, similar to the case $q_1 > X$.

$$Revenues_{MP}^{ST} = \begin{cases} 
q_2X + (q_1 - X)u + XMT, & \text{if } q_1 > X. \\
q_2 + (X - q_1)q_2 + XMT, & \text{if } q_1 < X.
\end{cases}$$

Profits for the Malt Plant are the sum of the two revenue terms minus the cost terms and is provided below. It becomes clear that the Malt Plant can choose an optimal $q_2^*$, but has to take into account what the response of the Farmer will be for each $q_2$. The $q_3$ is dependent on $q_2$, which is represented by $q_3^*(q_2)$. The decision is also dependent on all relevant parameters, represented by the three dots.

$$\pi_{MP}^{ST}(q_2; q_3^*(q_2), ...) = Revenues_{MP}^{ST} - Costs_{MP}^{ST}$$

**Farmer**

Finally, also the Farmer wants to optimize its profit and can determine an optimal $q_2^*$ in order to achieve this goal. However, the Malt Plant already knows the Farmer’s optimal response of $q_3$ for a specific $q_2$. So, the profit function of the Farmer is already employed by the Malt Plant to find the Farmers response.

Similarly to the profit function of Heineken and the Malt Plant we will separate the profit function into revenues and costs. Two cases of the revenue function apply to the Farmer. In the case where $q_2 > W$, the Farmer can sell $W$ at an agreed price of $r_3$ to the Malt Plant. Of the total yield $Y$ from the Farmer, the percentage of barley that does not meet specifications
B can be sold as feed barley for the market value of feed barley $F$. This creates extra revenues of $YBF$ for the Farmer.

In the case where $q_2 < W$, the Farmer sells $q_2$ for the agreed upon price of $r_3$ to the Malt Plant. The remaining quantity available for sale $W - q_2$ can be sold to the spot market. However, the price for each additional ton of barley sold outside the contract will decrease. The first ton of barley outside contract $q_2$ is sold for the spot price $S$, while the second ton of barley sold outside the contract is sold at $S - \frac{1}{2}d$. This process is repeated up to $W - q_2$. Higher levels of the discount factor $d$ will result in a slower decrease in price for excess barley. Again, revenue for barley that did not meet malting barley specifications is equal to $YBF$.

$$Revenues_{ST}^F = \begin{cases} Wr_3 + YBF, & \text{if } q_2 > W. \\ q_2r_3 + \sum_{i=1}^{W-q_2} i(S - \frac{i}{2}) + YBF & \text{if } q_2 < W. \end{cases}$$

Also, the Farmer is faced with input costs $i_3$ and production costs $c_{3}^{sh}$, which are depending on the Farmer’s cropping decision $q_3$. No separate cases apply for the costs, merely a multiplication of $i_3 + c_{3}^{sh}$ with $q_3$ will provide the Farmer’s costs.

$$Costs_{ST}^F = q_3(i_3 + c_{3}^{sh})$$

By subtracting the costs of the revenues we can calculate the Farmer’s profits. It is equal to the sum of the two revenue terms minus the cost function and is given in the equation below. The Farmer’s profit is dependent on $q_3$, which it can freely choose, and other relevant parameters in the Soft-Tolling model.

$$\pi_{ST}^F (q_3; ...) = Revenues_{ST}^F - Costs_{ST}^F$$
5.3 Hard-Tolling

The motivation for Heineken to pursue Hard-Tolling instead of Soft-Tolling is to reduce financing costs within the supply chain, that will reduce COGS for Heineken. However, because of the inventory-ownership construction Heineken has to free up Working Capital to finance these commodities and will incur risks that were previously allocated to the Malt Plant. The reduction in COGS is related to the amount of working capital required by Malt Plants. The credit leverage multiplied by total NWC requirements of suppliers indicates the discount in pricing. The height of NWC that Heineken needs to free up are easily deducted from these calculations. A trade-off between the reduction in input price and increased risks from Heineken’s perspective is necessary to make an substantiated choice. We will first study the sequence of events, then how the Hard-Tolling model is solved. Next, the risk allocation is discussed and we conclude with profit functions for each of the supply chain members.

Sequence of Events

In figure 5.4 the events in the Hard-Tolling model are summarized. At $t = 0$ all parties again observe the distributions of random variables that affect them and fixed contract prices. Between $t = 0$ until $t = 1$ all supply chain members choose their optimal contract sizes. Similar to the Soft-Tolling model Heineken can first initiate the malting contract quantity $q_1$ with the Malt Plant. However in the Hard-Tolling model Heineken also can decide on contract size $q_2$ with the Farmer. Finally, the Farmer responds with a $q_3$ decision. At $t = 1$ all quantities and corresponding prices are fixed.

From $t = 1$ until $t = 2$ demand $X$ will be realized and the Farmer delivers the minimum of $q_2$ and the delivery capacity $W$. Because the barley contract $q_2$ is between the Farmer and Heineken, Heineken is responsible for ordering the remaining quantity $Z - \min(q_2, W)$ at the spot markets. The Malt Plant acts as a processor and merely offers the infrastructure for converting the barley in malt within the $q_1$ quantity for the agreed upon price at $t = 1$. Finally, at $t = 2$ all revenues and costs for all parties are realized and the profits can be calculated.

Figure 5.4: Timeline of Events Model 2 Hard-Tolling

Model Solving

In the Hard-Tolling model there will be some level of coordination, because Heineken can jointly determine the optimal $q_1^*$ and $q_2^*$. However, it needs to take the Farmer’s response of $q_3^*$ into account for each decision on $q_2$. This PM is thus partly coordinated and instead of
three self-profit maximizing firms, only Heineken and the Farmer are able to make decisions to maximize expected profit. Similar to the Soft-Tolling model, backward induction will be employed to determine the optimal \( q_2^* \). Assuming the Farmer will determine its optimal \( q_3^* \) to maximize expected profits based on any given \( q_2 \), Heineken will take into account \( q_3^*(q_2) \) for its decision. Heineken can then determine \( q_1^* \) and \( q_2^* \) to maximize expected profit.

<table>
<thead>
<tr>
<th>Type of Risk</th>
<th>Farmer</th>
<th>Malt Plant</th>
<th>Heineken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand uncertainty</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Conversion rate</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Yield risk</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Price malt out-spec</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Price spot feed barley</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Price spot malt barley</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Quality failure barley</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Quality failure malt</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Table 5.3: Risk allocation for Hard-Tolling

Risk Allocation
Table 5.3 shows how risks are divided among supply chain members in the Hard-Tolling model, which differs from the Soft-Tolling model. Heineken and the Malt Plant are both still exposed to demand uncertainty. The Malt Plant invoices Heineken for tons of malt converted to barley, so therefore the Malt Plant is exposed to demand risk, albeit lower than in the Soft-Tolling model.

In the Soft-Tolling case Heineken agrees upon a fixed conversion factor with the Malt Plant. In the Hard-Tolling model the conversion risks are transferred to Heineken. In the Hard-Tolling model yield risk will also transfer to Heineken. If the realized yield is lower than the contract size, the Farmer will only deliver what is available and relies on Act of God clause in the contract to avoid penalties. Price risk of the malt out-spec is also transferred to Heineken, because Heineken owns the barley and malt during the conversion process. The uncertain feed price now affects the Farmer as well as Heineken. At the end of the period if there is barley left, Heineken has to salvage this at the feed price. For the Farmer the barley that fails to meet specifications can be sold as feed barley, exposing them to quality failure risk of barley and the spot price of feed barley. In cases where the Farmer’s yield is larger than expected the excess malting barley is sold outside the contract for the spot price. The procurement function of the spot malting barley has switched to Heineken in the Hard-Tolling case, making them also exposed to spot price risk. Figure 5.5 graphically shows how the supply chain streams flow in the Hard-Tolling case.
5.3.1 Profit functions Hard-Tolling

In this section we will provide the profit functions for the Hard-Tolling case. Since they are similar to the Soft-Tolling case, we will not explain as exhaustively as in the previous section. Heineken’s profit function will be discussed first and secondly we will elaborate on the profit function of the Malt Plant. The Farmers profit function is no different from the Soft-Tolling case, so we will omit the discussion in this section.

Heineken

In the Hard-Tolling model, Heineken can determine not only $q_1$, but also $q_2$. Heineken has to evaluate the specific $q_2^*(q_2)$ reactions and solve for $q_1^*, q_2^*$. Since Heineken is responsible for the procurement of barley, the cost function with the same cases defined in the Soft-Tolling model for the Malt Plant, is now applicable for Heineken. We refer the reader to the Soft-Tolling model in the previous section for an explanation. The difference between the two functions is that malting costs are no longer included in the barley cost function anymore. A separate malt cost function for Heineken will determine the costs for malting (and brewing).

$$Barley\ Costs_{HT} = \begin{cases} W_{i_2} + (Z - W)S, & \text{if } q_2 > Z > W. \\ W_{i_2} + (Z - W)S, & \text{if } Z > q_2 > W. \\ q_2i_2 + (Z - q_2)S, & \text{if } Z > W > q_2. \\ q_2i_2 + (Z - q_2)S, & \text{if } W > Z > q_2. \\ W_{i_2} + (Z - W)F, & \text{if } q_2 > W > Z. \\ q_2i_2 + (Z - q_2)F, & \text{if } W > q_2 > Z. \end{cases}$$

Besides costs for procuring barley, Heineken has malt and brewing related costs. Two cases apply for these costs, which are dependent upon demand realization $X$ and $q_1$. When $q_1 > X$, the cost function consists of three terms. The first term is the malting fee $(p_2 + c_2^{hf})$ that the
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Malt Plant charges Heineken per ton of malt and the costs for brewing from Heineken \( c_1^h \), which need to be multiplied by actual demand realization \( X \). Besides the regular amount, Heineken is now also responsible for the re-processing of the malt that did not meet specifications. The quantity of malt that does not meet specifications, is equal to demand realization \( X \) multiplied with malt failure \( M \). Costs per ton of malt is equal to the malting fee \( p_2 + c_2^{hf} \).

Next to this, when \( q_1 > X \), Heineken needs to pay a penalty to the Malt Plant equal to \( q_1 - X \) multiplied by the penalty costs \( u \), similar to the Soft-Tolling model.

In the second case, where \( q_1 < X \) applies, the cost function behaves differently. Up to the contract size \( q_1 \), Heineken will procure the malting services from the Malt Plant that cost \( p_2 + c_2^{hf} \) per ton of malt and incur brewing costs \( c_1^h \). Costs for malt are different when the demand realization \( X \) is larger than the contract size \( q_1 \). The Malt Plant will add a malting premium \( e \) for every ton of malt processed, making the malting fee equal to \( p_2 + c_2^{hf} + e \).

The brewing costs are equal to \( c_1^h \) for Heineken and the amount where the malting fee and the brewing costs have to be paid for is equal to \( X - q_1 \). Similar to the first case, malt that did not meet specifications needs to be re-processed. This is \( XM(m_2 + c_2^{hf}) \) again.

\[
Malt Costs_{HT} = \begin{cases} (p_2 + c_2^{hf} + e)X + XM(p_2 + c_2^{hf}) + (q_1 - X)u, & \text{if } q_1 > X. \\ (p_2 + c_2^{hf} + c_1^h)q_1 + (p_2 + c_2^{hf} + e + c_1^h)(X - q_1) + XM(p_2 + c_2^{hf}), & \text{if } q_1 < X. \end{cases}
\]

Heineken’s revenue is independent from contract quantity \( q_1 \) and thus has only one case. Actual demand realization \( X \) is multiplied by Heineken’s selling price to customers \( r_1 \), explaining the first term. The last term is the malt that did not meet specifications after the malting process, which can be sold to alternatives. Volume of the malt that did not meet specification is demand realization \( X \) multiplied by malt failure percentage \( M \), and the selling price of this malt is equal to \( T \).

\[
Revenues_{HT} = Xr_1 + XMT
\]

The profit for Heineken is the revenue term minus the sum of the two cost terms. Heineken can determine \( q_1^* \), but also has the ability the determine \( q_2^* \) taking into account the Farmer’s response. This is expressed by the term \( q_2^*(q_2) \). Furthermore Heineken also has to base its decision on other relevant parameters that influence the profit, represented by the dots. The total profit function for Heineken in the Hard-Tolling model is stated below.

\[
\pi_{HT}^{HT}(q_1, q_2; q_2^*(q_2), ...) = Revenue_{HT} - BarleyCosts_{HT} - MaltCosts_{HT}
\]

**Malt Plant**

In the Hard-Tolling model the Malt Plant is not responsible anymore for the procurement of barley, which simplifies his profit function tremendously. First, the costs of the Malt Plant in the Hard-Tolling case will be considered. Deviating from the Soft-Tolling case, the cost function of the Malt Plant behaves similar on all regions in the Hard-Tolling case. The production costs for the Malt Plant in the Hard-Tolling case are equal to \( c_2^{hf} \) and need to be multiplied by the demand realization \( X \). Also the malt that did not meet specifications will be malted again by the Malt Plant, the quantity is equal to \( X \) multiplied by \( M \) and the costs \( c_2^{hf} \) are similar. This explain the cost function for the Malt Plant in the Hard-Tolling case.

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Concerning the revenue function, it consists of two terms, which are distinguished by the difference between malt demand realization \( X \) and the malt quantity contract \( q_1 \). The revenue of the Malt Plant is equal to the malt costs for Heineken, minus the brewing costs. When \( q_1 > X \), three separate terms in the revenue function can be identified. The first is the malting fee \( (p_2 + c_{2f}^h) \) that the Malt Plant charges Heineken per ton of malt demand realized \( X \). Secondly, the penalty costs in case demand realized \( X \) was lower than the contract size \( q_1 \), a penalty costs of \( u \) per ton of malt will be charged for every ton missing in the contract \( (q_1 - X) \). Finally, the malt that did not meet specifications, quantity equal to demand realized \( X \) multiplied by malt failure \( M \) will be invoiced to Heineken for the same malting fee \( p_2 + c_{2f}^h \).

In the case where \( q_1 < X \), the Malt Plant will invoice Heineken the malting fee \( p_2 + c_{2f}^h \) for every ton of malt up to the contract size \( q_1 \). Furthermore, realized demand \( X \) above the contract \( q_1 \), will include an extra profit, which is the malting premium \( e \), that comes on top of the malting fee \( p_2 + c_{2f}^h \). The amount is equal to the difference between demand realization \( X \) and contract size \( q_1 \), which is \( X - q_1 \). Similar to the first case, malt that did not meet specifications will be invoiced to Heineken for the same malting fee, summing up to a revenue of \( XM(p_2 + c_{2f}^h) \).

Profits of the Malt Plant are equal to the revenue function minus the costs function. The profit function is stated below, which shows that the Malt Plant has no decision variable. The advantage of Hard-Tolling for the Malt Plant is that Heineken will incur the risks, previously allocated to the Malt Plant. On the other hand the Malt Plant has to give up control.

\[
\pi^{HT}_{MP} = Revenue^{HT}_{MP} - Costs^{HT}_{MP}
\]
5.4 Contract Farming

The motivation for Heineken to implement Contract Farming is also to reduce financing costs within the supply chain, which results in a COGS reduction for Heineken. From Heineken’s perspective even more Working Capital is required for this PM than in the Hard-Tolling model, although the COGS can be reduced even further. Another advantage is that Heineken now has complete control and can make all the quantity decisions throughout the supply chain. A trade-off between an increase in Working Capital, higher direct risks, extra control over the supply chain and the COGS reduction is necessary for Heineken to make a good decision. We will again first study the sequence of events, then how the Contract Farming model is solved. Risk allocation is discussed after and we conclude with profit functions for all supply chain members.

**Sequence of Events**

In figure 5.6 the timeline of events is graphically shown. In the Contract Farming model Heineken has full control over the supply chain and is able to make all the quantity decisions, irrespective of preferences from other participants in the supply chain. At $t = 0$ Heineken observes random variables and prices offered from the Malt Plant and the Farmer. Between $t = 0$ and $t = 1$ Heineken determines $q_1^*$, $q_2^*$, and $q_3^*$ simultaneously.

Between $t = 1$ and $t = 2$ demand is realized and all parties comply with contractual obligations. The Farmer delivers total yield $Y$ to Heineken and he gets paid based on actual output. Heineken will salvage the barley that fails specification at the feed price $F$ and send the minimum the contract size $q_2$ and good malting barley $W$ to the Malt Plant $\min(q_2, W)$. Since Heineken is responsible for procurement of barley, the remaining quantity $Z - \min(q_2, W)$ is ordered at the spot market. The Malt Plant will convert the barley into malt to meet actual demand $X$. The Malt Plant gets rewarded for malting services that are being delivered to Heineken. At the end of $t = 2$ all revenues and costs are realized and profits can be derived.

![Figure 5.6: Timeline of Events Model 3 Contract Farming](image_url)

**Model Solving**

In the Contract Farming model there will be full coordination because Heineken can solely determine $q_1^*$, $q_2^*$ and $q_3^*$, without taking preferences from the Malt Plant and the Farmer into account. There is a difference between the PMs concerning the $q_2$ decision. In the Hard-Tolling and Soft-Tolling model the $q_2$ was an actual contract between two independent firms. However, in the Contract Farming model Heineken is already owner of the seeds and there is no need to explicitly contract on the barley quantity.
However, in order to safeguard comparability between the three models, the $q_2$ decision will still be included. The $q_2$ should now be interpreted as the amount that Heineken wants to send to the Malt Plant, given that it is already owner of the barley yield. In this manner, Heineken is still in the opportunity to earn money if yields $Y$ are high and he can sell the malting barley to the spot markets at the decreasing profit function rate. But it can also determine to ship all barley from the Farmer to the Malt Plant. In reality this $q_2$ can be altered to match the actual circumstances, but we will consider $q_2$ as a policy decision that must be complied with in all times. The profitability of Heineken in the Contract Farming is therefore a lower bound on profits and could be increased if Heineken is able to deviate from the policy decision $q_2$.

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<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Quality failure barley</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Quality failure malt</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Table 5.4: Risk allocation for Contract Farming

**Risk Allocation**

Table 5.4 shows how risks are divided in the Contract Farming model amongst Heineken, the Malt Plant and the Farmer. Since Heineken is now owner of the commodity very early in the supply chain, it is exposed to even more risks than in the Hard-Tolling model. The Contract Farming model can best be described as the most risky PM for Heineken in terms of potential downside. Similar to the Hard-Tolling model, the Malt Plant is only exposed to some risk of demand uncertainty $X$. This is because the Malt Plant is reimbursed for malting services, which are exposed to demand fluctuations. The Farmer does not have to finance the variable input costs (such as seeds, fertilizers, etc), but is still exposed to some degree of yield risk $Y$. We have assumed that Heineken is responsible for the $q_3$ decision and the corresponding costs, however only pays the Farmer for actual yield rate. In this manner, Heineken incentivizes the Farmer to crop most efficiently and effectively. Without this compensation scheme, Farmers would have little incentive to maximize their yields if they were given their seeds and fertilizers from Heineken. These are the only two risks that are present at Heineken’s suppliers in the Contract Farming model, the rest of the risks are allocated to Heineken. In figure 5.7 the supply chain is displayed under the Contract Farming model.
5.4.1 Profit functions Contract Farming

In this section the profit functions for the Contract Farming case are presented, due to similarities we will again not explain as extensively as in the Soft-Tolling section. However, we will emphasize the differences between the different PMs. Since the profit functions for the Malt Plant are exactly the same to the Hard-Tolling section, we will omit these functions in this section and refer the reader to the previous section. Heineken’s and the Farmer’s profit function are different from the previous models, therefore these will be discussed.

Heineken

In this PM Heineken will pay the Farmer and the Malt Plant a cropping fee and tolling fee respectively. The six cases in the barley cost function in the Contract Farming model have the same bounds as the Hard-Tolling case. However, the costs for actual procurement of the barley are different because it depends on the yield realization $Y$. For all cases the amount of barley that Heineken will pay for depends on the $q_3$ decision multiplied by the input price $i_3$ (seeds) of the Farmer. Next to this the Farmer will receive a cropping fee $(c_f^3 + p_3)$, which consists out of the production costs and profit for the Farmer in the Contract Farming model. Heineken has agreed to pay this cropping fee for every ton of barley which is realized $Y$, irrespective of the quality. For all the cases the costs for barley are thus equal to $q_3i_3 + (c_f^3 + p_3)Y$. Next to procurement costs of barley, all other cases are the same as the Hard-Tolling case, therefore we refer the reader to that section for more explanation.
Barley Costs$^{HT}_H = \begin{cases} 
q_3 i_3 + (c'_3 + p_3)Y + (Z - W)S, & \text{if } q_2 > Z > W. \\
q_3 i_3 + (c'_3 + p_3)Y + (Z - W)S, & \text{if } Z > q_2 > W. \\
q_3 i_3 + (c'_3 + p_3)Y + (Z - q_2)S, & \text{if } Z > W > q_2. \\
q_3 i_3 + (c'_3 + p_3)Y + (Z - q_2)S, & \text{if } W > Z > q_2. \\
q_3 i_3 + (c'_3 + p_3)Y + (Z - W)F, & \text{if } q_2 > W > Z. \\
q_3 i_3 + (c'_3 + p_3)Y + (Z - q_2)F, & \text{if } W > q_2 > Z. 
\end{cases}

The Malt Costs function has already been defined in the Hard-Tolling section, the only difference is that the production costs for Heineken are now equal to $c'_1$ instead of $c_1$. This is caused because the financing costs for Heineken have increased in the Contract Farming model. Besides this, the rest of the function is the same. Therefore, we refer the reader to the previous section for more explanation of the function.

\[
\text{Malt Costs}^{CF}_H = \begin{cases} 
(p_2 + c^{bf}_1)X + XM(p_2 + c^{bf}_2) + (q_1 - X)u, & \text{if } q_1 > X. \\
(p_2 + c^{bf}_2 + c'_1)q_1 + (p_2 + c^{bf}_2 + e + c'_1)(X - q_1) + XM(p_2 + c^{bf}_2), & \text{if } q_1 < X.
\end{cases}
\]

Heineken’s revenues in the Contract Farming model includes a comparison between the delivery capacity $W$ function and the $q_2$ decision. Because of the extra amount of barley that Heineken can sell if the delivery capacity $W$ turns out to be higher than the contract size $q_2$. In the case where $q_2 > W$, Heineken can sell the realized demand of malt $X$ for a price of $r_1$. The malt that did not meet specifications, equal to the malt demand $X$ multiplied by the malt failure percentage $M$, can be salvaged at a price of $T$. In the Contract Farming model Heineken now also is responsible for the quality failures of the Farmer concerning the barley. Heineken receives compensation for the barley that does not meet malting barley specifications, which explains the third term. Realized yields $Y$ need to be multiplied by the barley failure percentage $B$, in order to attain the quantity eligible to be sold as feed barley. The price Heineken receives for this barley is equal to the current feed price $F$.

If $q_2 < W$, the revenue function is the same except for the last term. We will only deal with this term in our explanation here. For every ton of barley above the contract size $q_2$ up to the delivery capacity $W$, Heineken will receive compensation. This compensation will decrease if the barley capacity increases above the contract size $q_2$. This function is explained in the Soft-Tolling section for the Farmer, the reader is referred for more explanation.

\[
\text{Revenues}^{CF}_H = \begin{cases} 
X r_1 + XM + YBF, & \text{if } q_2 > W. \\
X r_1 + XM + YBF + \sum_{i=1}^{W-q_2} i(S - \frac{i}{q_2}), & \text{if } q_2 < W.
\end{cases}
\]

Heineken’s profit is equal to the revenue term minus the cost term, given in barley quantity and malt quantity, which is provided below. Heineken now needs to choose an optimal $q^*_1$, $q^*_2$, and $q^*_3$. They do not have to take into account preferences of other supply chain participants.

\[
\pi^{CF}_H(q_1,q_2,q_3;...) = \text{Revenue}^{CF}_H - \text{BarleyCosts}^{CF}_H - \text{MaltCosts}^{CF}_H
\]
Farmer

The Farmer in the Contract Farming model does not have a decision variable, but his profits are dependent upon the yield realization \( Y \). No different cases apply for the profit function of the Farmer. The revenue for the Farmer is equal to the cropping fee, which consists out of the production costs \( c^f_3 \) for the Farmer and the profit \( p_3 \). Multiplying the cropping fee \( c^f_3 + p_3 \) with the yield realization \( Y \), gives the revenue of the Farmer. The production costs now have an upper index \( f \) to indicate that these are the production costs under the Contract Farming model for the Farmer, since they are lower than in the Hard-Tolling and Soft-Tolling case. The production costs are fixed, similar to the other PMs and depend upon the cropping decision \( q_3 \). By multiplying the cropping decision \( q_3 \) with \( c^f_3 \) the production costs for the farmer are found. We provide the profit function in the equation below.

\[
\pi^{CF}_F = (c^f_3 + p_3)Y - q_3c^f_3
\]
Chapter 6

Business Case

In this chapter the three PMs are solved and compared via Monte Carlo simulation. Because the profit functions are difficult or even impossible to analyze via closed-form expressions, it was necessary to resort to simulation to provide insights into the performance of the three models. By selecting a fictive business case and using input parameters in the models that closely resemble the real-life situation, insights in the behavior of the three PMs are gained.

In section 6.1 the business case is presented and data and assumptions are substantiated. Next, in section 6.2 the results of the simulation for the three PMs are discussed and the profits and risks for all supply chain participants are given. In section 6.3 the distribution of profits for Heineken, the Malt Plant and the Farmer are analyzed via histogram plots. This section is concluded with a sensitivity analysis in section 6.4 to show the impact of specific input parameters on profits and standard deviation of the profits for Heineken and the total supply chain.

6.1 Introduction Business Case

In consultation with Heineken staff a fictive business case is selected. Input parameters are selected such that they closely match the real-life situation. The selected business case is an area in Eastern Europe, where Heineken currently employs Soft-Tolling. Heineken is interested in the performance of the other PMs. A pilot project, with a small amount of tons of malt was selected for the business case. The small scale of the business case will positively benefit the calculation speed of the simulation models. The results obtained for the small business case can be extrapolated to a larger business case, although caution is advised with extrapolation. In table 6.1 input parameters for the business case are provided and explained hereafter.
### Pricing

For each of the supply chain participants the input costs, production costs and profit margin are provided. Adding these terms together gives the selling price of the final product for each of the members in the supply chain. The penalty costs are set at €10 per ton of malt that Heineken does not procure from the Malt Plant within the contract quantity. In cases where demand realization is larger than the $q_1$ contract size, Heineken has to pay a malting premium for every ton of malt purchased outside the contract. The value of this malting premium has been set at €5. As explained in the assumptions in chapter 5, the Farmer would enjoy the largest profits by constantly increase its cropping decision $q_3$ if expected profits are higher than expected costs. To prevent this, a discount for malting barley above the $q_2$ contract size is assumed. The discount in the business case implies that for every 10 tons of barley above the contract size $q_2$ the price will drop with €1.

#### Cost of Funding

The cost of funding determines at which interest rate firms need to finance their working capital. According to Heineken’s press release, average cost of funding over 2014 was equal to 4%; however incremental cost of funding is much lower. Therefore Heineken’s costs of funding rate is set equal at 3%, a conservative estimate. Concerning suppliers, their cost of funding is higher than Heineken’s rate because of the differences in creditworthiness. The Malt Plant’s and the Farmer’s costs of funding are set at 8%, which is probably on the high side for Heineken’s larger suppliers. However, since Heineken will select suppliers for the business case with a higher cost of funding to make an interesting business case, it is plausible.

#### Number of Days

The number of days in the supply chain is based on insights and estimates from Heineken. In this specific area the Malt Plant is responsible for carrying the seasonal inventory of barley, which is explained by the large number of days committed (180) to Days Raw Material (RM) for the Malt Plant. The payment term towards Heineken, equal to the Accounts Receivable (AR), is 60 days and the inventory of Finished Good (FG) for the Malt Plant is equal to 45 days. The conversion process is relatively short and the Days Work-In-Progress (WIP) for the Malt Plant is set at 10 days. The payment term for the Farmer to the Malt Plant is only 7 days, which makes the Days Account Payable (AP) for the Malt Plant 7 and the Days AR
for the Farmer also. In this specific area the Farmer is not responsible for carrying seasonal inventory of barley, making the days FG for the Farmer equal to only 30 days. The Days Work-In-Progress for the Farmer is equal to the sowing period, which is around 180 days. Farmers only need to maintain Raw Materials for a short amount of time and we have set this at 30 days. Since payment terms are relatively short in the agricultural supply chain, this is equal to 7 days.

**Probability Distribution Functions of random variables**

The input parameters are deterministic and fixed for all of the Models, however a number of relevant variables are random and behave stochastically. The probability distributions functions can be described by a mean, \( \mu \), and a standard deviation, \( \sigma \). Because normal distributions are assumed for the random variables (see assumptions in section 5.2), only a mean and standard deviation are required. In reality random variables could be correlated, however because correlations are unknown and difficult to estimate, independence among random variables is assumed. The means and standard deviations for the probability distribution functions are presented in table 6.2 and are discussed hereafter.

<table>
<thead>
<tr>
<th>Random variables</th>
<th>Symbol</th>
<th>( \mu )</th>
<th>( \sigma )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley Failure</td>
<td>B</td>
<td>10%</td>
<td>1%</td>
</tr>
<tr>
<td>Malt Failure</td>
<td>M</td>
<td>10%</td>
<td>1%</td>
</tr>
<tr>
<td>Feed price</td>
<td>F</td>
<td>€150</td>
<td>€15</td>
</tr>
<tr>
<td>Spot price</td>
<td>S</td>
<td>€250</td>
<td>€25</td>
</tr>
<tr>
<td>Malt Out Spec price</td>
<td>T</td>
<td>€300</td>
<td>€10</td>
</tr>
<tr>
<td>Conversion Factor</td>
<td>K</td>
<td>1.25</td>
<td>0.0175</td>
</tr>
<tr>
<td>Yield</td>
<td>Y</td>
<td>( q_3 )</td>
<td>10% ( q_3 )</td>
</tr>
<tr>
<td>Malt Demand</td>
<td>X</td>
<td>10,000</td>
<td>500</td>
</tr>
</tbody>
</table>

Table 6.2: Probability distribution function parameters

The mean of the yield is equal to the \( q_3 \) decision of the Farmer and the standard deviation is 10% of the mean. The mean of the barley failure and the malt failure are both equal to 10% failure rate and the standard deviation is equal to 1%. The mean of the feed price is €150 and the standard deviation is €15 and the mean of the spot price is €250 and the standard deviation is €25. Prices for malt that did not meet specifications have a mean of €300 and a standard deviation of €10. The standard deviation of the conversion rate was selected such that 99% of all conversion rate realizations are between 1.20 and 1.30, with a higher probability of occurrence near the mean. Concerning demand, the lower estimation of standard deviation is based on a rather stable demand for beer and set at 5% of the mean, equal to 500 tons. The demand for beer expressed in malt quantity is equal to 10,000 tons of malt, resulting in 400,000 hectoliters of beer. It is assumed that 25 kg of malt is required for 1 hectoliter beer, but this can differ per type of beer. This can be altered to any amount of kilograms of malt required for 1 hectoliter of beer.

### 6.2 Results

In this section the results of the simulations for the input parameters and probability distribution functions stated in section 6.1 are provided. Profit for all members of the supply chain
is calculated according to profit functions defined in chapter 5. Heineken is exposed to more direct risks in the Hard-Tolling and Contract Farming case, which should result in a higher standard deviation of the profit. However, Heineken can insert their better cost of funding in these PMs and is therefore able to negotiate a price reduction. This price reduction needs to outweigh the costs for extra risks incurred, in order for Heineken to have higher profits in the Hard-Tolling and Contract Farming model.

The simulation starts with taking 100,000 draws from the random variables. For these 100,000 random draws the profits for Heineken, the Malt Plant or the Farmer are deterministically computed according to the profit functions defined in chapter 5. Expected profit and standard deviation of the profit for Heineken, the Malt Plant or the Farmer can be found by taking the average and standard deviation of these 100,000 values. The decision variables $q_1$, $q_2$, and $q_3$ affect the profits and the simulation will search for the optimal decision variables that will maximize the expected profit for each of the parties. The performed simulation can be defined as a Monte Carlo optimization simulation or stochastic optimization, because of the random objective function and the iterative way of solving for $q_1^*$, $q_2^*$, and $q_3^*$.

The randomness in the objective function, due to the simulation, does not result in a smooth objective function. Within MATLAB, FMINCON is a constrained optimization solver that is able to find local minima using the first derivative of the objective function. Because the objective function contains some random noise, the derivatives could be unreliable. Therefore, for the simulations we rely on PATTERNSEARCH within MATLAB from the Global Optimization Toolbox. This optimization technique is part of a class of direct search methods for optimizations and no derivative information is required to find global optima of objective functions. We rely on this optimization technique to reassure that MATLAB finds correct optimal values for $q_1^*$, $q_2^*$, and $q_3^*$.

For the specific input parameters, defined in section 6.1, a check is performed for multiple values of $q_1$, $q_2$, and $q_3$. In Appendix B the results are presented for this check, which clearly shows that profits are concave for the specified input parameters. Because profits are concave, it is possible to determine the optimal values for $q_1^*$, $q_2^*$, and $q_3^*$. Although the profits are concave for the specified input parameters and random variables, this does not mean that they always behave in the same manner. More derivative information is required to make this claim, however will be hard to accomplish due to the complexity of the profit functions. In table 6.3 the results for the simulation of the business case are summarized.

<table>
<thead>
<tr>
<th></th>
<th>Soft-Tolling</th>
<th>Hard-Tolling</th>
<th>Contract Farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_1^*$</td>
<td>10,592</td>
<td>9,809</td>
<td>9,680</td>
</tr>
<tr>
<td>$q_2^*$</td>
<td>14,750</td>
<td>14,750</td>
<td>14,704</td>
</tr>
<tr>
<td>$q_3^*$</td>
<td>16,280</td>
<td>16,280</td>
<td>15,869</td>
</tr>
<tr>
<td>$E[π]$ Heineken</td>
<td>€3,996,375</td>
<td>€4,027,484</td>
<td>€3,999,945</td>
</tr>
<tr>
<td>Malt Plant</td>
<td>€247,148</td>
<td>€332,721</td>
<td>€332,783</td>
</tr>
<tr>
<td>Farmer</td>
<td>€250,232</td>
<td>€250,232</td>
<td>€318,112</td>
</tr>
<tr>
<td>$σ[π]$ Heineken</td>
<td>€200,381</td>
<td>€216,464</td>
<td>€230,258</td>
</tr>
<tr>
<td>Malt Plant</td>
<td>€56,211</td>
<td>€16,767</td>
<td>€17,148</td>
</tr>
<tr>
<td>Farmer</td>
<td>€257,075</td>
<td>€258,022</td>
<td>€204,751</td>
</tr>
</tbody>
</table>

Table 6.3: Results Business Case
Optimal contract decisions
In table 6.3 the optimal contract decisions are presented. The \( q_1^* \) decision in the Soft-Tolling case is higher than in the Hard-Tolling and Contract Farming case. The reason for this is that in the Soft-Tolling case Heineken can only use the \( q_1 \) decision to hedge for higher spot price risks, while in the Hard-Tolling and Contract Farming case the \( q_1 \) merely stands for the malting capacity that Heineken requires. In the Hard-Tolling and Contract Farming case Heineken can separate these two decisions, which gives them more flexibility. In the Hard-Tolling case, Heineken will decide upon the same \( q_2^* \) contract size as the Malt Plant does in the Soft-Tolling case. Only in the Contract Farming case Heineken determines different \( q_2^* \) and \( q_3^* \) contract sizes, which is caused by the fact that Heineken does not need to take the preferences of the Farmer and Malt Plant into account.

Profits
These specific input parameters and probability distribution functions lead to the highest expected profits for Heineken in the Hard-Tolling case, followed by the Contract Farming and Soft-Tolling model. However, the difference with regards to profits between the Soft-Tolling and Contract Farming model is very small, only €3,000. Benefits for the Hard-Tolling model compared to the Soft-Tolling model is over €30,000 for Heineken. For the Malt Plant and Farmer the Hard-Tolling and Contract Farming models are much more profitable than the Soft-Tolling model. For the Malt Plant an increase of almost €85,000 is possible by switching to the Hard-Tolling or Contract Farming model. For the Farmer the benefit is only apparent in the Contract Farming model, but the benefits are over €65,000. The large increase in profits for the Farmer and Malt Plant are the result of Heineken taking over their risks and financing the inventories.

Standard Deviation of Profits
It was assumed that the risks for Heineken are larger in the Hard-Tolling and Contract Farming model compared to the Soft-Tolling model. Table 6.3 substantiates this claim, because the standard deviation of the profit is increasing for Heineken for the models with more upstream intervention. Comparing the Soft-Tolling model and Hard-Tolling model for Heineken, standard deviation increases with 8%, while for the Contract Farming Heineken’s standard deviation increases with 15%. For both the Farmer and Malt Plant intervention from Heineken is desirable, because the standard deviation of the profit will decrease in all cases for both the Farmer and Malt Plant.

In summary, in the business case mainly suppliers will benefit from higher upstream intervention because Heineken is taking over the risks and finances the inventories. Heineken’s profit will only increase slightly in the Hard-Tolling model, but the risks will also increase. For the Malt Plant and Farmer profits are higher and standard deviation is lower, making it an interesting alternative for Heineken’s suppliers. The reduction in selling price based on financing cost is not enough to compensate for the extra risks that Heineken incurs. A potential remedy for Heineken is to request for a further reduction in selling price of suppliers or reallocate some of the costs back to suppliers. Because profits of the total supply chain increase, due to a reduction in financing cost, it will be possible to create win-win situations that are beneficial for Heineken as well as the Farmer and the Malt Plant.
CHAPTER 6. BUSINESS CASE

6.3 Histogram Plots Profits

Histogram plots provide insights in how the profits for Heineken, the Malt Plant, and the Farmer are distributed. By analyzing the plots, it is possible to check if profits are normally distributed or to which families of distributions they belong. Any potential skewness or kurtosis can be identified by the histogram plots. If there are large deviations from the normal distribution, we could reconsider using the standard deviation of the profits as an appropriate measure of risk. Other suitable measures of risk could be Value-At-Risk (VAR), if for example the profits are negatively skewed. In this section the individual histogram plots for Heineken, the Malt Plant and the Farmer are discussed and analyzed.

Heineken

In figure 6.1 the profits for Heineken for the three PMs are provided. Heineken’s profits for the three PMs appear to be normally distributed without kurtosis or skewness. The variance is highest in the Contract Farming model and lowest in the Soft-Tolling model, which matches with the results in table 6.3. Considering expected profits, Soft-Tolling and Contract Farming have virtually the same mean, while the expected profit of the Hard-Tolling model is clearly largest. This again matches with the results of expected profits for Heineken presented in table 6.3.

Malt Plant

For the Malt Plant large differences exist between the different PMs, looking at the histogram plots. The Soft-Tolling clearly has the lowest profit, since the mode of the profits is located far to the left, compared to the Hard-Tolling and Contract Farming model. The histogram plots for Hard-Tolling and Contract Farming are very similar, although not completely identical. The minor deviation between these plots is related to different contract sizes between the two models, as can be seen in table 6.3. The mode of the profits and the variance of the profits, depicted in figure 6.2, matches the results as shown in table 6.3. While more tests can demonstrate if profits follow a normal distribution, according to the histogram plots they appear to be normally distributed.

Figure 6.1: Histogram Heineken’s profits
Farmer
Looking more closely at the profit function of the Farmer, a clear departure from normality in the Soft-Tolling and Hard-Tolling case is visible. Since profits are similar for these two models, only the Hard-Tolling plot is visible. Therefore these two histograms will be discussed simultaneously as one. Two modes in the profits are visible in the histogram plot, which is caused by underlying profits of the Farmer. Because the Farmer can sell the barley up to $q_2$ for the contracted price, the distribution of profits within the contract are skewed towards $q_2$. On the contrary, the Farmer only sells barley outside the contract if delivery capacity $W$ is above the contract size $q_2$. Profit of barley sold outside the contract is therefore skewed in the opposite direction of barley sold within the contract. Because of these two underlying factors, the profits for the Farmer in the Hard-Tolling and Soft-Tolling model are not normally distributed. In the Contract Farming model, the Farmer is only remunerated for their value-added service and no opposing underlying profit streams are present. In the Contract Farming model, profits for the Farmer appear to be normally distributed.
6.4 Sensitivity Analysis

In order to gain insights of the impact of specific parameters we have set up a sensitivity analyses around the base case values presented in the business case. Sensitivity analysis will clarify the impact of the parameter for the individual PMs and the differences between the three PMs. The performance of the PMs can be captured by the expected profits and the variance of the profits, however also the contract decisions are important to study to gain insights in the behavior of the system under various circumstances.

Because the choice for one of the PMs will not only impact Heineken but also the entire supply chain, we take both perspectives for the sensitivity analysis. As was mentioned before, in our quantitative models we assume that Heineken is responsible for all of the risks that were originally located at Malt Plants and Farmers. If however supply chain profits would increase in the Hard-Tolling or Contract Farming model and Heineken’s profit on the contrary would decrease, there are opportunities for gain-sharing and reallocate some of the risks and costs back to Heineken’s suppliers to create win-win situations, where both the suppliers and Heineken can lower risks or increase their profit.
Spot Price ($S$)
The expected spot price $S$ has a large impact on the profits of the supply chain as well as Heineken’s profit. If the expected spot price is lower than the contract price, the maximization model will search for the lower bound on the contract decisions because barley is cheaper from the spot market. Because Heineken selects a low contract size $q_1$, the Malt Plant will react with a small contract size $q_2$ as well. In the case of low expected spot prices, both the profit of Heineken and Malt Plant can increase. On the contrary, the Farmer’s profit will decrease because of the low expected spot price and lower contract sizes. The total supply chain can benefit in the Contract Farming model, because financing costs are taken out and thus total profits are largest in this Procurement Model. There is a U-shaped profit function for the total supply chain, because higher expected spot prices contribute positively to the Farmer’s profit.

In line with expectations, under the Contract Farming model Heineken incurs a higher risk than in the Hard-Tolling and Soft-Tolling model. From Heineken’s perspective, risks remain relatively flat for Soft-Tolling and Hard-Tolling with higher expected spot prices. Heineken will namely react with larger contract sizes, thereby reducing the need for more expensive spot barley. Considering the risks for the total supply chain, these increase slightly with higher expected spot prices. The Contract Farming model provides the lowest standard deviation of the profits from a total supply chain perspective.

![Figure 6.4: Heineken profit & standard deviation under various Spot Prices](image1)

![Figure 6.5: Total Supply Chain profit & standard deviation under various Spot Prices](image2)
Demand Volatility ($X$)

Malt demand volatility has a high impact on the profits of mainly Heineken, because higher levels of volatility result in lower profits for all three PMs. This is consistent with standard models in Operations Management literature. In cases where demand volatility is low, Contract Farming and Hard-Tolling become more profitable than Soft-Tolling. Heineken will therefore be more inclined to implement Hard-Tolling or Contract Farming in regions where demand volatility is low. The profits of the total supply chain are fairly stable with different levels of malt demand volatility. This is mainly caused because Heineken increases contract sizes facing larger demand volatility, which benefits the Malt Plant and the Farmer. Benefits for the Malt Plant and the Farmer therefore offset the negative effects for Heineken, making total supply chain profits fairly constant. Profits of the total supply chain are again highest in the Contract Farming model, because total financing costs in the supply chain are reduced.

An increase in malt demand volatility results in higher volatility of the profits for Heineken, because Heineken is directly exposed to demand uncertainty and its consequences. Contract Farming gives Heineken the biggest risks, because the risks are transferred to Heineken. However, the overall supply chain will benefit from higher intervention from Heineken because supply chain risks are lowest in the Contract Farming model.

![Heineken Profit & Standard Deviation](image1)

(a) Profit  
(b) Standard deviation

Figure 6.6: Heineken profit & standard deviation under various Demand Volatilities

![Total Supply Chain Profit & Standard Deviation](image2)

(a) Profit  
(b) Standard deviation

Figure 6.7: Total Supply Chain profit & standard deviation under various Demand Volatilities
**Uncertain Yield (Y)**

Yield uncertainty is an important factor to consider because yields are often highly uncertain in areas where upstream intervention is required to secure commodity origin. It will be interesting to look at the impact of yield uncertainty for Heineken individually as well as the total supply chain. Beginning with Heineken, the yield uncertainty doesn’t impact Heineken in the Soft-Tolling model, which coincides with the distribution of the risks. However, in the Hard-Tolling model Heineken needs to take into account the Farmers cropping decision and is impacted by the yield uncertainty. This effect is even stronger in the Contract Farming case, because here Heineken directly incurs yield risks. When yield uncertainty is low, upstream intervention can become even more profitable for Heineken. However, higher levels of yield uncertainty negatively impact Heineken’s decision for more upstream intervention. Interesting to see is that yield uncertainty negatively impacts the total supply chain. This is because Farmers are directly exposed to higher losses and Malt Plants will anticipate with higher contract decisions, with the accompanying risk of write-offs at the end of the period.

Looking more closely at the risks from Heineken’s perspective, only Contract Farming exposes Heineken to significantly more risks. Soft-Tolling does not impact Heineken’s risk and Hard-Tolling will only have a small impact if yield uncertainty becomes very large. Interesting to see is that risks of yield uncertainty will increase the volatility of profits for the entire supply chain. This effect is similar to demand uncertainty, only in this case mainly the Farmer and Malt Plant are impacted by higher levels of yield uncertainty. In case of demand uncertainty, mainly Heineken was impacted. Again, risks from the total supply chain perspective are lowest in the Contract Farming model and highest in the Soft-Tolling model.

![Figure 6.8: Heineken profit & standard deviation under various Yield Uncertainties](image1)

![Figure 6.9: Total Supply Chain profit & standard deviation under various Yield Uncertainties](image2)
Quality Failures (M & B)
The strictness of quality requirements and quality failures has a large impact on Heineken’s profits. First, Heineken’s profits and the total supply chain profits are discussed and thereafter the risks from both perspectives. Looking at Heineken’s profit function, upstream quality failures do not impact the profits under the Soft-Tolling case. These risks are allocated to Heineken’s upstream suppliers, who are financially liable for negative effects of quality failures. In the Hard-Tolling case, Heineken is directly exposed to quality failure of the malt, which explains the decreasing profit under increasing quality failures. This effect for Heineken is even larger in the Contract Farming model. However, in the case of low quality failures the Contract Farming is even become more profitable for Heineken than the Hard-Tolling model. Interesting to see is that for the total supply chain, quality failures are a zero-sum game and profits remain equal for various levels of quality failures. Similar to the other sensitivity analyses profits are again highest in Contract Farming followed by Hard-Tolling and Soft-Tolling.

Considering Heineken’s risks, an increase in is expected for higher levels of quality failures. The results show that quality failures do lead to larger risks for Heineken under the Contract Farming model. However, by increasing contract size risks can be kept fairly constant over increasing levels of quality failures. This applies for all PMs and is not limited to Heineken, but this is also true for the total supply chain. Similar to other sensitivities, risks are highest in the Contract Farming model for Heineken, but lowest for CF taking a total supply chain perspective. The decrease of standard deviation of profits for upstream suppliers offsets the increase in Heineken’s risks, which make Heineken better suitable of bearing the risks than upstream suppliers.

Figure 6.10: Heineken profit & standard deviation under various Quality Failure

(a) Profit
(b) Standard deviation

Figure 6.11: Total Supply Chain profit & standard deviation under various Quality Failures

(a) Profit
(b) Standard deviation
Heineken needs to make a strategic choice which PM to focus on going forward. With higher upstream involvement, Heineken is more exposed to direct risks in the supply chain and incurs more risk. Higher risks need to be offset by higher expected profits to make the extra risk worthwhile. Each PM can be considered as an individual asset with its own risk-return profile. By assigning different weights to each of the PMs, Heineken can construct various portfolios. With the set-up of the portfolios Heineken faces a mean-variance trade-off in terms of expected profits and risk, measured as standard deviation of the profits. In this chapter the three PMs are combined by using Modern Portfolio Theory (MPT) to identify the impact for Heineken in terms of profits and risks. MPT is a financial theory that aims to maximize expected profits, for a given level of risk, or equivalently minimize risk for a specific level of expected profits. Constructing a portfolio by assigning weights to each of PMs can minimize the risk from a portfolio perspective, as long as the PMs are not perfectly positively correlated.

In section 7.1 an introduction to the portfolio approach is provided and how Heineken can apply it. Section 7.2 gives insights in how the analysis is performed and what assumptions are included in the model in order to proceed with the calculations. In section 7.3 the results of the portfolio approach are presented for the specific business case at hand, which was provided in chapter 6. Results are again obtained via Monte Carlo simulation and in this chapter only Heineken’s perspective is taken.

7.1 Introduction Portfolio Approach

Each PMs is considered to be an individual asset with its own risk-return profile. It is possible to construct various portfolios, by assigning different weights to each of the PMs. If firms behave risk-neutral, their only interest is maximizing expected profit. Within each PM Heineken behaves risk-neutral and determines an optimal contract size that will maximize its profits. However, Heineken will construct the portfolio taking profits as well as standard deviation of the profits into account by taking a mean-variance approach. If profits between the PMs are not perfectly positively correlated Heineken can achieve diversification benefits by applying the portfolio approach. Two assets are perfectly positively correlated if their value moves in the same direction, by the same percentage, at the same time. Since it is highly unlikely that profits between the PMs possess these properties, Heineken will be able to lower its risk by exploiting this knowledge. Heineken’s performance with the portfolio approach is assessed by two criteria, which are expected profits and the standard deviation.
of the profits. The profit and standard deviation of the profits for the portfolio are explained in this section. First, a standard mean-variance optimization is discussed and subsequently the simulated mean-variance optimization utilized in this thesis.

**Standard Mean-Variance Optimization**

In standard mean-variance optimization, portfolio profits are the sum of weighted average profits for each of the assets that are included in the portfolio. Heineken has the ability to choose between three different assets, which are Soft-Tolling (ST), Hard-Tolling (HT), and Contract Farming (CF). The portfolio profit under standard mean-variance optimization is represented in the following equation, and the weights of the individual assets need to add up to 1. The expected profit for this three-asset portfolio can be calculated by taking the expectation of these three terms.

$$\pi_P = w_{st}\pi_{st} + w_{ht}\pi_{ht} + w_{cf}\pi_{cf}$$

s.t. \( \sum w_i = 1 \) \hspace{1cm} (7.1)

The variance of a three-asset portfolio is not equal to the weighted average of the variance of the individual assets, because the covariances among the individual assets has to be included. Covariances can also be expressed by correlations between two different assets. The covariance is the multiplication of the the weights of the individual assets with the standard deviations of the assets and the correlation between the specific individual assets. As an example, the covariance term between Soft-Tolling and Hard-Tolling is given.

$$\text{COV}_{st,ht} = w_{st}w_{ht}\sigma_{st}\sigma_{ht}\rho_{st,ht}$$

Variance of the portfolio is equal to the variances of the individual assets. Next to the individual assets’ variance, the covariance between each of the individual assets is incorporated in the portfolio variance. The following formula provides the standard mean-variance optimization portfolio variance.

$$\sigma_P^2 = w_{st}^2\sigma_{st}^2 + w_{ht}^2\sigma_{ht}^2 + w_{cf}^2\sigma_{cf}^2 + 2w_{st}w_{ht}\sigma_{st}\sigma_{ht}\rho_{st,ht} + 2w_{st}w_{cf}\sigma_{st}\sigma_{cf}\rho_{st,cf} + 2w_{ht}w_{cf}\sigma_{ht}\sigma_{cf}\rho_{ht,cf}$$

s.t. \( \sum w_i = 1 \) \hspace{1cm} (7.2)

**Simulated Mean-Variance Optimization**

A requirement of using standard mean-variance optimization is that portfolio profit is a linear combination of weights \( w_i \) and individual asset’s profit \( \pi_i \). In the following section in table 7.1 it is visible that this assumption of linearity is not met. The profit of the individual asset is dependent upon the weight \( w_i \) assigned to it. Because the linearity assumption does not hold, standard mean-variance optimization for the profit, as displayed in equation 7.1, is not applicable. The following formula is applied to determine the profit of the portfolio, where the profit \( \pi_i \) depends on the weight \( w_i \).

$$\pi_P = \pi_{st}(w_{st}) + \pi_{ht}(w_{ht}) + \pi_{cf}(w_{cf})$$

s.t. \( \sum w_i = 1 \) \hspace{1cm} (7.3)
Since linearity is assumed for both profit and variance, the portfolio’s variance can also not be calculated by standard techniques. In our models, the variance of the individual asset also depends on the weight \( w_i \) assigned to it. Similarly to the profit, a different function is used for the portfolio’s variance. In equation 7.2 the variance of the individual assets will become dependent on the weights of the individual asset \( w_i \), the result is provided in equation 7.4.

\[
\sigma_P^2 = \sigma_{st}(w_{st})^2 + \sigma_{ht}(w_{ht})^2 + \sigma_{cf}(w_{cf})^2 + 2\sigma_{st}(w_{st})\sigma_{ht}(w_{ht})\rho_{st,ht} + 2\sigma_{st}(w_{st})\sigma_{cf}(w_{cf})\rho_{st,cf} + 2\sigma_{ht}(w_{ht})\sigma_{cf}(w_{cf})\rho_{ht,cf}.
\]

(7.4)

We have to rely on simulation to measure the profits and risks for each of the individual assets with their specific weights \( w_i \) assigned. In the following section more details are provided on how the simulation is performed to obtain the profit and risk of any portfolio combination.

### 7.2 Set-up Analysis

In this section more explanation is provided on the set-up of the analysis that was necessary to gain insights in Heineken’s risks and profits. As explained before, because of nonlinearity of the individual assets’ profits and variance in their weights \( w_i \), standard mean-variance optimization is not applicable. Therefore, profits and variance need to be calculated by simulation for all potential weights \( w_i \) assigned. Going forward, total malt demand \( X \) is split in 10 boxes of 10% of malt demand. Because the weights of the portfolio need to add up to 1.00, the number of combinations is not equal to \( 10^5 \). If 100% is allocated to Soft-Tolling, there is nothing left to allocate to Hard-Tolling or Contract Farming and thus only 1 possibility exists. If 90% is allocated to Soft-Tolling, 10% can be allocated to either Hard-Tolling or Contract, which comes down to 2 possibilities. Every 10% decrease in Soft-Tolling results in one extra possibility for the construction of the portfolio. Therefore, in total 66 potential portfolios can be constructed \((1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 + 11 = 66)\), because the weights of the portfolios need to add up to 1.00.

By measuring profits and standard deviation of the individual assets, we can obtain for each of these 66 portfolios expected profit and the corresponding standard deviation. In table 7.1 the input data for the mean-variance optimization is provided. What is striking, is that the profits and standard deviations for the Soft-Tolling model behave relatively linear; on the contrary, the profits and standard deviation for the Contract Farming model are not linear. Weights under 30% are most profitable under the Contract Farming model corresponding with a high level of risk Heineken incurs. However, above 30% allocated to each of the PMs the Hard-Tolling model is the most profitable. Short-selling is not allowed in our portfolio approach, because this is not possible in real-life with PMs.
As mentioned earlier, correlations between individual assets has an impact on the variance of the total portfolio. From conversations with Heineken staff members, it was difficult to determine exact correlations among the three different PMs. Therefore, the correlations among the various Procurements Models are estimated to see the impact of specific correlation levels. In further research, procurement expenses over the last 10 years for malt could be compared for the different PMs to gain insights of the actual correlations.

By manipulation the impact of specific correlation factors to the portfolio’s profit and standard deviation is analyzed. Three scenarios for the correlations are identified and simulated: low correlation factor (0.25), medium correlation (0.50), and high correlation (0.75). For each of these three scenarios 66 portfolios are constructed, which makes it possible to create a scatterplot with standard deviation on the x-axis and profit on the y-axis of all 66 portfolios. The three different scenarios are provided in the equations below. Because of the lack of insights in the actual correlations, they are assumed to be the same between the different PMs within one scenario.

Scenario 1: Low correlation = \[
\begin{align*}
\rho_{st,ht} &= 0.25 \\
\rho_{st,cf} &= 0.25 \\
\rho_{ht,cf} &= 0.25
\end{align*}
\]

Scenario 2: Med correlation = \[
\begin{align*}
\rho_{st,ht} &= 0.50 \\
\rho_{st,cf} &= 0.50 \\
\rho_{ht,cf} &= 0.50
\end{align*}
\]

Scenario 3: High correlation = \[
\begin{align*}
\rho_{st,ht} &= 0.75 \\
\rho_{st,cf} &= 0.75 \\
\rho_{ht,cf} &= 0.75
\end{align*}
\]

Table 7.1: Profits and standard deviation for various allocations to Procurement Models

<table>
<thead>
<tr>
<th>$w_i$</th>
<th>$\pi_{st}(w_i)$</th>
<th>$\sigma_{st}(w_i)$</th>
<th>$\pi_{ht}(w_i)$</th>
<th>$\sigma_{ht}(w_i)$</th>
<th>$\pi_{cf}(w_i)$</th>
<th>$\sigma_{cf}(w_i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>€399,638</td>
<td>€20,038</td>
<td>€404,057</td>
<td>€21,831</td>
<td>€419,312</td>
<td>€26,866</td>
</tr>
<tr>
<td>20%</td>
<td>€799,275</td>
<td>€40,076</td>
<td>€808,445</td>
<td>€40,557</td>
<td>€819,064</td>
<td>€47,494</td>
</tr>
<tr>
<td>30%</td>
<td>€1,198,913</td>
<td>€60,114</td>
<td>€1,212,820</td>
<td>€62,336</td>
<td>€1,217,593</td>
<td>€69,727</td>
</tr>
<tr>
<td>40%</td>
<td>€1,598,550</td>
<td>€80,152</td>
<td>€1,616,771</td>
<td>€83,704</td>
<td>€1,615,485</td>
<td>€92,079</td>
</tr>
<tr>
<td>50%</td>
<td>€1,998,188</td>
<td>€100,191</td>
<td>€2,019,639</td>
<td>€107,734</td>
<td>€2,013,068</td>
<td>€115,219</td>
</tr>
<tr>
<td>60%</td>
<td>€2,397,825</td>
<td>€120,229</td>
<td>€2,422,429</td>
<td>€127,910</td>
<td>€2,410,450</td>
<td>€137,937</td>
</tr>
<tr>
<td>70%</td>
<td>€2,797,463</td>
<td>€140,267</td>
<td>€2,824,002</td>
<td>€148,171</td>
<td>€2,807,725</td>
<td>€160,425</td>
</tr>
<tr>
<td>80%</td>
<td>€3,197,100</td>
<td>€160,305</td>
<td>€3,226,340</td>
<td>€172,770</td>
<td>€3,205,153</td>
<td>€183,975</td>
</tr>
<tr>
<td>90%</td>
<td>€3,596,738</td>
<td>€180,343</td>
<td>€3,628,367</td>
<td>€190,347</td>
<td>€3,602,461</td>
<td>€206,511</td>
</tr>
<tr>
<td>100%</td>
<td>€3,996,375</td>
<td>€200,381</td>
<td>€4,027,484</td>
<td>€216,464</td>
<td>€3,999,945</td>
<td>€230,258</td>
</tr>
</tbody>
</table>
7.3 Results

In this section the results of the portfolio approach for Heineken with the three different correlation levels are presented. For each scenario the minimum variance portfolio is given, which is the composition of the portfolio that ultimately provides Heineken with the lowest risk. Furthermore, the composition of the portfolio that maximizes Heineken's profit, defined as max-profit portfolio, is provided. The efficient frontier is a combination of assets that gives Heineken the lowest amount of risk for a given level of return or the highest profit for a given level of risk. The efficient frontier is also identified for each scenario and presented in the graphs. Risks are most likely higher in portfolios that maximize Heineken’s profit, but based on its risk preference Heineken is able to decide on an appropriate portfolio. However, Heineken should always choose a specific combination of assets that is located on the efficient frontier.

In order to calculate the profits and standard deviation of the 66 portfolios the input data in table 7.1 is combined with equations 7.3 and 7.4. Equation 7.3 determines Heineken’s profit for a specific allocation of weights to the individual PMs, while equation 7.4 provides the corresponding variance for this allocation. In order to determine the standard deviation, the square root of the variance is taken. All 66 portfolios have their own profit and standard deviation and will be plotted in a scatterplot in this section for the three different levels of correlation.
**Scenario 1: Low correlation**

In figure 7.1 the profits and standard deviations of all 66 potential portfolios that can be constructed by using the portfolio approach are provided. The efficient frontier, indicated by the green line is also apparent in figure 7.1. Furthermore, the three portfolios where 100% is allocated to an individual PM are also provided. It is clearly visible that the constructed portfolios outperform each of the individual PMs. This implies that Heineken can significantly improve its performance by using a portfolio approach.

With low correlations among the PMs the minimum variance portfolio is constructed by allocating 40%, 30%, and 30% to Soft-Tolling, Hard-Tolling, and Contract Farming respectively. Comparing the minimum variance portfolio with the maximum profit portfolio the decrease in variance is significant, a reduction of 25% compared to the maximum profit portfolio. By taking this extra risk Heineken can increase their profit by €20,000. The allocation to PMs between the min-variance and max-profit portfolio differ. Heineken will allocate 90% to Hard-Tolling and 10% to Contract Farming to achieve the highest expected profit for this specific business case.

<table>
<thead>
<tr>
<th></th>
<th>Min-Variance Portfolio</th>
<th>Max-Profit Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft-Tolling</td>
<td>40 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Hard-Tolling</td>
<td>30 %</td>
<td>90 %</td>
</tr>
<tr>
<td>Contract Farming</td>
<td>30 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Profit</td>
<td>€4,028,964</td>
<td>€4,047,679</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>€150,458</td>
<td>€198,773</td>
</tr>
</tbody>
</table>

Table 7.2: Low correlation Min-Variance & Max-Profit Portfolio
Scenario 2: Medium correlation
In the case where the profits of the PMs are correlated to a medium extent, figure 7.2 starts to look different. In the low correlation case, the efficient frontier was clearly visible, while in this scenario the shape of the curve is flatter. This implies that Heineken has fewer opportunities to diversify with higher correlations among the PMs. Again, the three individual PMs are outperformed heavily by the portfolio approach. Looking deeper into the minimum variance portfolio, the weights for the individual PMs has remained the same with medium correlations. Although weights are the same, the standard deviation has increased compared to the low correlation cases. This is related to smaller diversifying opportunities when markets exhibit higher levels of correlation. Standard deviation has increased from €150.458 to €173.504, which is roughly 10% increase. Expected profits are similar to the low correlation case.

The portfolio that maximizes Heineken’s profit also did not change in scenario 2 compared to scenario 1. This makes sense, because expected profits are merely a weighted average of the individual assets and different correlation levels do not impact expected profit. However, looking into the standard deviation of the max-profit portfolio an increase is visible compared to scenario 1. Again, this is related to lesser opportunities for diversification if markets are becoming more correlated.

<table>
<thead>
<tr>
<th></th>
<th>Min-Variance Portfolio</th>
<th>Max-Profit Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft-Tolling</td>
<td>40 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Hard-Tolling</td>
<td>30 %</td>
<td>90 %</td>
</tr>
<tr>
<td>Contract Farming</td>
<td>30 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Profit</td>
<td>€4.028.964</td>
<td>€4.047.679</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>€173.504</td>
<td>€205.104</td>
</tr>
</tbody>
</table>

Table 7.3: Medium correlation Min-Variance & Max-Profit Portfolio
Scenario 3: High correlation

The final scenario is where markets are highly correlated and Heineken has even less opportunities for risk diversification. The efficient frontier is even flatter in this scenario, which is clearly visible in figure 7.3. In the case of high correlations, the weights of the minimum variance portfolio are different from medium and low correlation. Where Heineken would apply a 40%, 30%, and 30% portfolio for Soft-Tolling, Hard-Tolling, and Contract Farming respectively with low and medium levels of correlation, in the third scenario Heineken can achieve the lowest standard deviation by assigning 60% of total demand to Soft-Tolling and 40% Hard-Tolling. The standard deviation again increases to €191.198, which is an increase of roughly 10% compared to scenario 2. Profits are considerably lower compared to the other two scenarios, which is a result of the changed minimum variance portfolio. The portfolio to achieve the maximum profit is still the same in scenario 3 and has similar profits, but the standard deviation has increased. Comparing the standard deviation of scenario 2 (€205.104) with scenario 3 (€211.245), the increase of around €6.000 is the same as the increase from scenario 1 to 2.

![Portfolio approach](image)

Figure 7.3: High correlation 0.75 Portfolio Approach

<table>
<thead>
<tr>
<th></th>
<th>Min-Variance Portfolio</th>
<th>Max-Profit Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft-Tolling</td>
<td>60 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Hard-Tolling</td>
<td>40 %</td>
<td>90 %</td>
</tr>
<tr>
<td>Contract Farming</td>
<td>0 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Profit</td>
<td>€4,014.596</td>
<td>€4,047.679</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>€191.198</td>
<td>€211.245</td>
</tr>
</tbody>
</table>

Table 7.4: High correlation Min-Variance & Max-Profit Portfolio
Chapter 8

Conclusions, limitations and recommendations

In this chapter the conclusions of the research, its limitations and recommendations for Heineken and future research are provided. In section 8.1 the research questions that were introduced in chapter 1 will be answered. Because the models make use of various assumptions and expectations of input parameters, the limitations are set out in section 8.2. Finally, in section 8.3 we will give recommendations for Heineken and for future academic research in this area.

8.1 Conclusions

In this section, the questions that served as guidelines for this research are answered.

1. How is procurement at Heineken for the barley-malt supply chain currently organized?

Heineken has operations in more than 70 countries worldwide and procurement for barley and malt is organized differently throughout the world. Three Procurement Models, each distinct in nature with varying upstream intervention are used at Heineken.

The Soft-Tolling model is most commonly applied throughout the world, mainly in developed regions and areas where barley is not a specialty crop. In this model Heineken is merely fixing the price of future deliveries, but no active intervention in the upstream supply chain is taking place. The Hard-Tolling is applied in areas where active attention from Heineken is required to stimulate Farmers to crop barley. The main difference between Soft-Tolling and Hard-Tolling is that ownership during the conversion process is already located at Heineken instead of the Malt Plant and Heineken needs to contract with Farmers as well. The Contract Farming model is applied in regions where Farmers are credit constrained and Heineken is forced into financing the Farmer to secure commodity origin. In our Contract Farming model it is assumed that Heineken is responsible for delivering and financing the seeds, fertilizers and all variable input costs. Furthermore, Heineken is exposed to most of the supply chain risks that were previously allocated to Farmers.
2. What information is required in order to model pre-shipment finance?

The information required has been identified and discussed throughout this thesis, and is summarized in a Framework that allows pre-shipment financing to be applied to a supply chain in general.

Important elements to take into account are the risks and their distribution between participants in the supply chain, a breakdown of the costs, the working capital requirements and financing costs, mechanisms that specify how to deal with quality failures for example, and the amount of inventories in the supply chain. All of these elements are translated into profit functions for all participants in the supply chain. This allows for quantitative comparison in terms of profits and risks of different pre-shipment financing models.

3. What quantitative models can be designed that can help Heineken for operational and strategic decision-making?

For each PM identified at Heineken, a mathematical model was developed that allows Heineken to quantitatively substantiated decision-making instead of basing decisions on guesswork.

The quantitative models can sharpen Heineken’s overall replenishment strategy on a strategic level. The models provide insights in the sensitivities towards profits and risks and Heineken can choose a specific PM that matches its desired risk-return profile. Investing in one’s own upstream supply chain is an interesting alternative for excess cash. Because it cannot only provide Heineken with benefits, but also strengthen suppliers.

Furthermore, operational decision-making can be enhanced by the MATLAB simulation tool. The quantitative model enables Heineken to determine optimal contract sizes for each of the PMs, given a set of input parameters and show the impacts on profits and risks. One of the benefits is that implicit knowledge from buyers and industry experts can be translated into the quantitative models and shared with all relevant stakeholders. Heineken can unlock value by using this knowledge and turn it into actionable insights, that was previously not available.

4. Should Heineken increase upstream supply chain collaboration?

This research shows that upstream supply chain collaboration via pre-shipment financing of commodities that are ultimately destined for Heineken is not a zero-sum game. On the contrary: by leveraging Heineken’s scale and good credit rating it can enlarge the total supply chain profits and divide the benefits among the participants accordingly. We highly recommend Heineken to follow up on the opportunities that we have presented.

In a business case we confirmed that Heineken can maximize its expected profits by applying the Hard-Tolling model (although an increase in risks occurred as well). The total supply chain profit is always biggest and supply chain risks are always smallest in the case with high upstream intervention by Heineken, as was demonstrated in the sensitivity analysis in chapter 6. Even if Heineken does not always benefit in our sensitivity analysis, possibilities for gain sharing exist. Because the Malt Plant and Farmer will incur both a higher profit and a lower variance with more upstream intervention, Heineken is able to claim higher discounts on pricing than merely the savings in financing costs. This can result in an overall positive business case for Heineken via re-allocation of risks and costs to suppliers.
5. What is an optimal allocation between the various Procurement Models?

In chapter 7 a portfolio approach was developed that can provide Heineken with insights on the optimal portfolio of PMs based on a risk-return preference by mean-variance optimization. Because it is highly unlikely that profits are perfectly positively correlated, Heineken can diversify risks by applying a portfolio approach. However, higher levels of correlations between the PMs reduce this risk-mitigation opportunity.

The efficient frontier is defined as the portfolios that will maximize expected profits, for a given level of risk, or equivalently, minimize risks for a specific level of expected return. If Heineken would select a different portfolio then the ones located on the efficient frontier, it can always enhance its choice by lowering the risk for the same expected return or increasing expected return for the same level of risk. This is an important conclusion. To provide an answer to this research question, we conclude that there is not one portfolio for Heineken that is optimal in terms of expected profits and risks. However, there are many suboptimal portfolios that are not located on the efficient frontier. Heineken should thus always construct a Procurement Portfolio located on the efficient frontier to maximize its performance.

In summary, the main contribution of this research is a novel Working Capital Inventory Ownership approach to pre-shipment financing. The developed framework can be applied for other supply chains as well and create insights in expected profits, risks, and working capital requirements from a buyer and total supply chain perspective. Specifically for Heineken, three PMs have been modeled. A risk-return trade-off that matches Heineken’s preference will determine the choice for one of the PMs, and an optimal allocation between the different models should always be located on the efficient frontier. We show that by leveraging Heineken’s credit rating, financing costs can be reduced throughout the entire supply chain and value can be created, presenting interesting avenues of potential for Heineken.

8.2 Limitations

In this study assumptions are made that warrant cautiousness in extrapolating the results to a larger business case or different setting. In this section the most important limitations are discussed.

Risks for upstream ownership of the commodities is not explicitly taking into account in the models, although in real-life this could lead to losses and negatively impact Heineken’s decision for more upstream intervention. Suppliers of Heineken will probably have more customers and inventories need to be assigned to Heineken. Since Malt Plants and Farmers do not separate inventories for different customers in silo’s, this could lead to confusion of which inventories belong to Heineken and result in increased risks for Heineken. Assigning inventories to Heineken via a Mass-Balance system, based on underlying documentation stream, can offer a solution for this problem. Costs for implementation of Mass-Balance should be included in the calculations of a potential business case. Also costs for managing the inventories should be taken into account, where internal documentation of operations in Mexico can be taken as a reference for the costs.

In our quantitative analysis we studied a one-period model and end-of-period inventories have to be salvaged at a discount, resulting in negative effects on profit. This is a common assumption in analytical models, because multi-period models are difficult to analyze due to their complexity. If there is no need to salvage the commodities, the results of the analysis
merely represent a lower bound on profit. Associated with the assumption of a one-period model we do not look at the impact of safety stocks and inventories to cope with uncertainty in demand. By keeping safety stocks, this would lower the need for more expensive commodities from the spot market although holding costs have to be charged that will impact profitability. The results of safety stocks on the outcomes are inconclusive, because a trade-off should be made between the need for expensive commodities from the spot markets and holding costs.

Concerning quality failures, the 0-1 pass fail mechanism is assumed based on random draws from a failure rate distribution, which is a simplification of real-life situation. In practice the recipe for a specific beer can be altered to cope with deviating quality specifications or Heineken could accept the delivery of malt to use for a different type of beer brand. By implementing a more complex quality inspection mechanism that can take into account more options in dealing with quality failures, the applicability for Heineken can increase.

Results from the business case and portfolio approach are dependent upon specified input parameters, which are inserted in the quantitative models. With different input parameters or correlation factors for example, the results could be considerable different. Correct parameterization of the models is important, because the parameters heavily influence the results.

The two main performance measures defined in our research are expected profits and standard deviation of the profits, although working capital requirements is a third criterion that could explicitly be used as a performance measure. We have considered working capital required as an endogenous consequence of applying one of the PMs, similar to profits and risks. We have not evaluated working capital as a separate performance criterion. In the portfolio approach for example the working capital required is not depicted on the axis or in the sensitivity analysis no measure of Working Capital is provided. This could be added as an explicit performance criterion in future research.

8.3 Recommendations

In this section the recommendations for Heineken and future research will be discussed.

8.3.1 Heineken

Three important recommendations for Heineken, resulting from this research, are identified.

- **Decision-support tool**: Use the optimization model within specific PMs to find optimal contract sizes and apply this to decision making and improve Risk-Management activities.

- **Parameterization and Configuration**: All parameters and stochastic variables can be observed in real-life, Heineken should exert effort to parameterize the model to match exact specifics to the quantitative models to get better insights in performance. Furthermore, Heineken could configure the model to reallocate risks and costs back to suppliers in consultation with suppliers to create insights in different configurations of supply chains.

- **Strategic management tool**: Apply the insights developed in this thesis to improve and substantiate Heineken’s global replenishment strategy and determine, based on Heineken’s risk preference if higher upstream intervention is desirable. Also Heineken
could check if the current allocation to different PMs is located on the efficient frontier, otherwise Heineken is not fully reaping the benefits of diversification and its global scale.

8.3.2 Future Research

Results in this thesis are a good starting point, but future research might expand in a number of different directions, which are provided in this section.

- **Relaxation of Assumptions:** Going forward a number of assumptions could be relaxed to attain new insights from an academic perspective. We will now present a number of relaxations.

  - Limited availability of spot markets can be an interesting direction for future research. Seifert et al (2012) analyzed a three-echelon supply chain with lost sales and concluded that upstream intervention is highly beneficial for downstream firms in cases where downstream profit margins are larger than upstream profit margins. Although there are differences between this research and Seifert et al (2012), his approach is applicable to the quantitative models and profit functions.
  
  - Multi-period models are in general far more complex than one-period models; although can give better insights in actual decision-making in real-life. Extension of the current one-period models to multi-period models, can allow for inventories to be carried over to the next period, let firms act as traders in commodities and results in better decision-making.

- **Different Configurations of the Models:** In our current models the configuration that best matches reality has been modelled, although different configurations can be studied in future research.

  - Various types of contracts between Heineken and upstream suppliers can be employed to achieve supply chain coordination. The literature on coordination in supply chains by applying contracts is vast and therefore extensions in these directions are within reach. The literature describes many types of contracts, such as buy-back, revenue-sharing contracts or option contracts to realize coordination.
  
  - In our models we assumed that firms are risk-neutral and merely maximize their expected profits, however explicitly taking risks into account in the objective functions could provide new insights from an academic perspective. By use of utility functions or risk-averse objective functions the research could be extended.

- **Risk Reduction Pricing:** In this research we have assumed that Heineken is responsible for all the risks and costs for the risks in the Hard-Tolling and Contract Farming model. However, it would also be possible to reallocate these risks back to Heineken’s suppliers or Heineken could ask for a higher reduction in input costs, not merely based upon the savings in financing costs. With a game-theoretic approach, the reduction in selling price resulting in equilibrium profits can be studied.
Appendices
Appendix A

Heineken Global Procurement

HGP was founded in 2012 to centralize procurement, create more insights that can be used for cost savings and mitigate risks for a company-wide perspective. HGP has three concrete benefits and goals:

Managing input price volatility
Heineken uses various commodities for beer brewing. Commodity prices fluctuate and Heineken is therefore managing the volatility of input prices. There is no standardized exchange for barley, so price and quantity fixation are settled mainly via fixed-delivery contracts with suppliers. The Commodity Price Risk Policy contains specific guidelines on how Heineken's Risk Management department should take position during the year locking in prices and quantities. These activities are extra important because Heineken cannot pass on the costs for rising costs of ingredients to customers directly. Selling prices of beer are fixed in advanced with supermarkets and bars.

Leveraging Heineken's scale
One of the priorities on the agenda of Heineken is to leverage its global scale. A concrete realization of this priority is the establishment of Heineken Global Procurement to centralize spend. Four purchasing models are currently implemented by HGP and are shown in figure A.1. In table A.1 a short explanation of each of the models is provided. The desired end result is that all Heineken spend is managed by HGP in the Buy-Sell model, but this involves large-scale implementation of systems and new procedures.
Supplier Finance
Financial collaboration with suppliers in order to lower total supply chain costs is possible in many forms. A large distinction can be made between pre-shipment and post-shipment financing (Wuttke, Blome, & Henke, 2013). Currently, Heineken is active in post-shipment financing solutions. Heineken went live with Supplier Finance with a multi-bank solution in 2012; an approved invoice with an irrevocable agreement from Heineken to pay at the due date is the trigger for banks to provide liquidity to Heineken’s direct suppliers. This gives direct suppliers the opportunity to receive liquidity after only a couple of days instead of the original payment terms. On the other hand this gives Heineken the opportunity to harmonize payment terms to achieve working capital benefits.
Appendix B

Optimal Contract Decision Values

Because we rely on simulation to find optimal values for $q_1$, $q_2$, and $q_3$ the gradient of the profits for Heineken, the Malt Plant and the Farmer are studied. In order to find optimal values for $q_1$, $q_2$, and $q_3$ the profits should be concave, otherwise the maximizations will not locate a global optimum. In figure B.1 the profits for a range of $q_1$ values is shown, which indicates a concave profit function.

Concerning the Malt Plant, figure B.2 shows the course of profits for a range of $q_2$ values on the x-axis. Because the profit of the Malt Plants is also dependent on $q_3$, each line represents a different value for $q_3$. The blue, green, red, light blue, and purple line indicate low levels of $q_3$ and the Malt Plants profit remain flat for higher levels of $q_2$. However, when $q_3$ becomes large enough there is concavity in the Malt Plant’s profit.

The dependency between $q_2$ and $q_3$ is also visible for the Farmer in figure B.3. When the Farmers is faced with a larger contract size $q_2$ from the Malt Plant, its profits will increase in $q_3$ initially. However, since we have assumed a decreasing profit function for Farmers for quantities sold outside the contract, the profits will eventually decrease. This re-assures concavity of the profit function of the Farmer.
Figure B.1: Profit Heineken

Figure B.2: Profit Malt Plant

Figure B.3: Profit Farmer
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