The Influence of Volatile Raw Material Prices on Inventory Valuation and Product Costing

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Abstract

Efficient product costing and inventory valuation are much emphasized in today's manufacturing environment because of their importance in management decisions. However, especially volatile raw material prices bring challenges to reliability of product costing and inventory valuation. This relatively little regarded, but important viewpoint is investigated in this research.

The research problem is stated as follows: *how should raw material flow around raw material inventory be valuated?* In literature review eight factors that should be considered when choosing inventory valuation and product costing methods were determined. Based on these factors three variables that affect the efficiency of raw material inventory valuation and product costing were defined, and they were tax shield benefits, product costing accurateness and how well information reflects the performance of a company. For the empirical part a framework was formed based on these three variables.

In the empirical part a simulation model was built and based on the model raw material inventory valuation methods were evaluated. A scenario analysis was done in order to analyze generality and robustness of raw material inventory valuation methods. Using the simulation model and the scenario analysis different raw material inventory valuation methods are evaluated in a real company environment, and results that cannot be derived analytically are disclosed.

By using a correct raw material inventory valuation method business can be much improved. In the case company on which the simulation model is based, product costing error can be decreased by 14 % of product costs and inventory value fluctuation by 7 % of inventory value by just choosing adequate inventory valuation method. The main determinant of the magnitude in improvements is raw material price behavior. In the case of high inflation the benefits of using correct inventory valuation method can be very great. Also volatility of raw material prices affects results significantly.

The main contribution of this research is the investigation of the effects of uncertain raw material prices in the context of product costing and inventory valuation. The main result that contradicts current research is that FIFO (first-in first-out) should not be used for raw material accounting. In general, LIFO (last-in last-out) and market prices are efficient raw material inventory valuation methods. Yet, the choice between these two depends on objectives of management accounting. However, it was observed that material flow behavior has no significant effect on the ranking of different raw material inventory valuation methods, and thus the main results can be generalized to different companies.

Keywords: inventory valuation, product costing, raw material price, FIFO, LIFO, weighted average cost, market price
Number of pages (including appendices): 117

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Voimakkaasti vaihtelevien raaka-ainehintojen vaikutukset varastonarvostukseen ja tuotekustannuslaskentaan

Tiivistelmä

Tuotekustannuslaskenta- ja varastonarvostusmenetelmien merkitys korostuu etenkin nykyajan tuotantoympäristöissä, koska kyseiset menetelmät ovat tärkeitä johdon apuvälineitä. Kuitenkin voimakkaasti vaihtelevat raaka-ainehinnat madaltavat kustannuslaskennan ja varastonarvostuksen luotettavuutta. Tämä on tärkeä ja kirjallisuudessa vähälle huomiolle jäänyt aihe, ja siksi se on otettu tämän tutkimuksen kohteeksi.

Tutkimusongelma tässä työssä voidaan lausua seuraavasti: *kuinka raaka-ainemateriaalivirta raaka-ainevaraston ympärillä tulisi arvostaa?* Kirjallisuuskatsauksessa löydettiin kahdeksan yleistä tekijää, jotka tulisi ottaa huomioon arvostusmenetelmien valinnassa. Näiden pohjalta määritettiin kolme raaka-aineiden arvostuksen hyvyyteen vaikuttavaa tekijää, jotka olivat tuotekustannuslaskennan tarkkuus, informaation oikeellisuus ja verosuojan hyödyt. Empiiristä osaa varten muodostettiin viitekehys edellä mainittujen kolmen tekijän pohjalta.

Empiirisessä osassa rakennettiin simulointimalli, jonka perusteella arvioitiin yleisimpiä raaka-aineiden varastonarvostusmenetelmiä, joita olivat FIFO (first-in first-out), LIFO (last-in first-out), painotetun keskiarvon menetelmä, markkinahintamenetelmä ja kolmen kuukauden keskiarvo -menetelmä. Tutkimuksessa toteutettiin myös skenaarioanalyysi, jonka avulla arvioitiin tuloksien yleistettävyyttä sekä arvostusmenetelmien eri tilanteisiin sopeutuvuutta. Simulointien ja skenaarioanalyysin perusteella raaka-aineiden varastonarvostusmenetelmien toimivuutta arvioitiin oikeassa tuotantoympäristössä.

Arvostusmenetelmien oikealla valinnalla yrityksen suorituskykyä voidaan selkeästi parantaa. Caseyrityksessä tuotekustannuslaskennan virhettä voidaan pienentää 14 %:lla tuotteen kustannuksista ja varastonarvon heilahtelua 7 %:lla varastonarvosta valitsemalla oikea varastonarvostusmenetelmä. Muuttuja, joka pääosin määrää parannuksien suuruuden, on raaka-ainehintojen käyttäytyminen. Korkean inflaation tapauksissa menetelmien erot toisiinsa nähden kasvavat merkittävästi. Myös raaka-ainehintojen heilahtelujen suuruudella on paljon merkitystä.

Merkittävin tämän tutkimuksen lisä olemassa olevaan tutkimukseen on satunnaisesti muuttuvien raaka-ainehintojen vaikutusten arviointi tuotekustannuslaskennan ja varastonarvostuksen kontekstissa. Tärkein tulos, joka on ristiriidassa aiemman kirjallisuuden kanssa, on se, että FIFO-menetelmää ei tulisi käyttää raaka-ainevirtojen arvostukseen. Yleisesti parhaiten sopivat menetelmät ovat LIFO ja markkinahintamenetelmä, ja valinnan näiden kahden välillä tulisi perustua johdon laskentatoimen tavoitteisiin. Tutkimuksessa huomattiin, että raaka-ainevirran käyttäytyminen ei vaikuta merkittävästi raaka-ainevaraston arvostusmenetelmien keskinäiseen järjestykseen, ja siksi tutkimuksen päätulokset voidaan yleistää erilaisiin yritysympäristöihin.

Asiasanat: varastonarvostus, tuotekustannuslaskenta, raaka-ainehinta, FIFO, LIFO, painotetun keskiarvon menetelmä, markkinahinta
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Helsinki, 6th of March
Hannu Suviolahti

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List of Symbols

y_t =output at time t
v = constant
β = coefficient of time
t = time
u_t = noise value (error term) at time t
μ = drift
θ_i = coefficient of noise value on the lag i
L^i = lag operator on lag i
α = smoothing factor
ϕ_i = coefficient of lag i value
η_i = coefficient of squared noise value at time t-i
κ_i = coefficient of variance at time t-i
σ_t^2 = variance at time t
f = forecasted value
n = number of observations
ε = error term
R^2 = coefficient of determination
$\overline{y}$ = average of all values of the dependent variable $\boldsymbol{y}$
$\hat{y}_i$ = estimated value of the dependent variable $\boldsymbol{y}$
$Inv(t)$ = inventory in kilograms at time t
$Iva(t)$ = inventory value at time t
$WAC(t)$ = weighted average cost at time t
$pup(t)$ = purchase price at time t
$pu(t)$ *or* pu_t = purchases in kilograms at time t
$pur(t)$ = purchases in euros in period t,
$S(t)$ = sales in kilograms in period t
a = sales-inventory-ratio
γ_s = one-month relative change
$\gamma_s[\boldsymbol{SS}(\boldsymbol{t})]$ = relative stainless steel price change between time t and time t-1
$\gamma_s[\boldsymbol{N}(\boldsymbol{t}-\boldsymbol{i})]$ = relative nickel price change between time t-i and time t-i-1
$\gamma_s[\boldsymbol{NI}(\boldsymbol{t}-\boldsymbol{i})]$ = relative global nickel inventory change between time t-i and time t-i-1
$\boldsymbol{npl}(\boldsymbol{t})$ = logarithmic nickel price at time t
$np(t)$ = nickel price at time t
$\bar{\sigma}^2$ = residual variance

$\boldsymbol{m}$ = total number of parameters estimated
$\boldsymbol{T}$ = sample size
ψ_i = average of variable i
σ_i = standard deviation of variable i
Z = randomly generated value from distribution N(0,1)
$\rho_{t,t-1}$ = correlation between variable at time t and at time t-1.
$\rho_{i,j}$ = correlation coefficient between outputs i and j
$Iuv(t)$ = inventory unit value at time t
$IVF(t)$ = inventory value fluctuation due to volatility of stainless steel prices
$RIVF$ = relative (=compared to inventory) IVF
$Iva_{WAC}(t)$ = inventory value with weighted average cost method at time t
PCA = product costing accurateness
$RPCA$ = relative PCA
$cu(t)$ = cost of stainless steel unit at time t
$mp(t+1)$ = market price of stainless steel unit at time t+1
$DWAC$ = difference between chosen inventory valuation method and weighted average cost method
$RDWAC$ = relative $DWAC$
TS = tax shield due to inventory value change
VTS = value of tax shield
$PV(TS)$ = present value of tax shield TS
r = discount rate for 3-month period
$PV(TTS)$ = present value of total tax shield over the 5-year interval simulated
$PV(TTS)_{3ma}$ = total present value of total tax shield with 3-month average method
TSP = tax shield profit
$TSPI$ = TSP to infinity
R = annual discount rate
V_0 = value of dividends at time 0
D_1 = dividends one year later from now
k = rate of return used for discounting cash flows from now to infinity
g = yearly growth of dividends
P_{RDWAC} = marginal price of measure $RDWAC$
P_{RIVF} = marginal price of measure $RIVF$
P_{RPCA} = marginal price of measure $RPCA$
$VIVS$ = value of inventory valuation system

1 Introduction

Management accounting has grown in importance in organizations since the 20th century when its effect on business performance became understood. The importance is straightforwardly derived: what cannot be measured cannot be managed, and what cannot be managed cannot be improved. If something cannot be measured, it is impossible to take correct actions. Nowadays competition across businesses is tough and profit margins are small, so every decision is important. Thus accurate management accounting information is extremely valuable. Choosing product lines, harvesting or acquiring businesses, hiring or firing personnel are some examples of matters that are heavily affected by management accounting information.

This research is about product costing and inventory valuation, which are essential areas in management accounting. These two areas have their importance, for example, in product pricing and profitability calculations. However, constantly changing and complex business environment brings a lot of challenges to product costing and inventory valuation. In some industries the number of products can be hundreds, thousands, or even tens of thousands. These products may be situated at a number of warehouses. The products may also be manufactured from various raw materials. Thus it is impossible for a manager to evaluate even the operations of his own company without getting accurate information from products and inventories. To get more accurate management accounting information, corporations have implemented various softwares. Management accounting is also a major part, for example, in different ERP-softwares. However, these softwares are very expensive, and thus the information must be acquired efficiently. So the challenge of acquiring accurate information as cheaply as possible still remains. Thus there is always need for management accounting research, especially in the area of product costing and inventory valuation.

1.1 Motivation

There has been a continuing controversy over the best method of appreciating material flow, especially in valuating inventory. There are many studies about choosing a correct inventory valuation method between FIFO (first-in first-out) and LIFO (last-in first-out). Some famous examples include Morse & Richardson (1983) and Dopuch & Pincus (1988). Many of these studies investigate how firms should choose a correct method based on one or two factors. These individual factors are important, but there is a need for research, which completely analyzes the factors, their effects on each other and answers the foremost question of choosing the optimal method taking all factors into consideration. This would be essential to companies, which are searching for an optimal method for them. For companies, it is the overall situation that matters, not the individual factors.

Another, but more important motivation to this research is that there exists no research that considers the effects of volatile raw material price movements when choosing optimal inventory valuation and product costing methods. There are studies that recommend LIFO under inflation (such as Wilson & Walter 2003), but these studies do not consider the effects of volatility in raw material prices. This is quite surprising, because raw material valuation is essential, especially in the upstream of the supply chain.

Volatility of raw material price brings problems to valuation of inventory. When prices increase or decrease substantially, inventory and material flow valuation follow a way behind. Then, for example, product costing and thus pricing goes wrong and management accounting figures (such as profit margin) cannot be trusted. Inventory valuation and product costing have also a straight effect on cash flow. Biddle (1980) estimated that the 105 firms in his study paid an average of nearly $26 million in additional federal income tax due to absence of optimal inventory valuation methods. Thus, huge savings can be achieved by choosing the correct method. But as Bar-Yosef & Sen (1992) conclude, when deciding an optimal accounting policy one must consider distortion of information as well as tax gains achieved. Thus companies are faced with an important, but challenging problem.

This research was motivated because of these two major gaps in current research, which were absence of overall analysis of all factors and volatility in raw material prices. These two gaps indicate that companies do not have guidelines for choosing the correct inventory valuation and product costing methods under volatile raw materials. After this research, companies struggling with fluctuating raw material prices should be able to analyze their situation a lot better than currently. A company struggling with these problems was selected as a case company to this research. The empirical study is based on the case company; in this way we are able to study the effects of fluctuating raw material prices on business of a successful and experienced company.

1.2 Research Problem and Objectives

Based on the previous, inventory valuation has major direct and indirect effects on cash flows of companies. The main direct effect is the effect on tax obligations. Inventory valuation and product costing affect indirectly by distorting information, and the distorted information makes difficult to make correct decisions. The focus of this research is to investigate inventory valuation and product costing to improve these direct and indirect effects. In addition, volatile raw material prices bring another challenge to appreciating inventory and the cost of products. Thus the research problem is constructed around volatile raw material, and the main objective is to discover the most efficient way to appreciate material flow around raw material inventory. So the research problem of this investigation can be stated as follows: *How should raw material flow around raw material inventory be valuated?*

First of all, in order to analyze product costing and inventory valuation under volatile raw material prices, price behavior of the raw material needs to be analyzed. For this study a case company was chosen, which is struggling with fluctuating stainless steel prices. These prices have been especially volatile during latest years. Thus the first objective is to model stainless steel price behavior.

After the behavior of the stainless steel price has been investigated, the main focus is on how the raw material flow should be appreciated. Before choosing actual methods to value raw material flow, the factors affecting ranking of valuation policies are considered. So the second objective is to determine the factors affecting raw material inventory valuation and product costing policy.

After the factors are determined, next task is to value the actual raw material flow. Inflow of raw material to inventory is clear, because it is valuated based on purchase prices. This is the only possible way. Then the first thing is to value this raw material when it is in the inventory. Thus the inventory valuation policy, that is the most efficient for companies, has to be investigated. So, the third objective of this research is to find out the most efficient way to value raw material inventory.

Finding the optimal way to value raw material inventory does not consider product costing. Flow out from inventory should be appreciated efficiently, because product costing is based on this appreciation. So the final objective is to discover the most efficient way to value raw material flow out of inventory.

Therefore, the objectives described previously are shortly as follows:

1. To model stainless steel price behavior
2. To find out factors that determine the most efficient raw material inventory valuation and product costing policy
3. To find out the most efficient way to value raw material inventory
4. To discover the most efficient way to value raw material flow out of inventory.

1.3 Limitations

When starting this research three major limitations were defined. First of all, this research considers product costing and inventory valuation on behalf of raw material. Raw material inventory here is limited from inbound to the boundary between company and its supplier. From outbound the raw material inventory is limited to the boundary between raw material inventory and production. That's why no end-products or semi-finished products are taken into account.

Second major limitation is due to specific raw material. Raw material in the case company, and thus in this research, is stainless steel. So, especially in the empirical part only stainless steel is considered, and no other raw material is taken into account.

Third limitation is that the empirical part of this research is based on the case company's environment. Therefore, all company-specific inputs and overall environment is based on the case company, and thus this research does not consider any other company.

1.4 Structure

This research is divided into two main parts: literature review and empirical research. First, in chapter 2 a literature review is covered, which has four parts. In the first part relevance of inventory valuation and product costing is considered, in the second part modeling of raw material behavior is discussed, the third part includes a review of product costing and in the final part inventory valuation methods are evaluated. Based on this literature review, a framework for the empirical part is constructed. The framework is introduced and analyzed in chapter 3, as well as the research methods used. The main aspect in the empirical part is formulation of the simulation model around the research problem. The simulation model is introduced in chapter 4 and results of the simulations are analyzed in chapter 5. In the last chapter the whole research is summed up and main conclusions are made.

2 Product Costing, Inventory Valuation and Price Fluctuation

In this literature review inventory valuation, product costing and modeling of prices are covered. This literature review is divided into four subsections. First, relevance of inventory valuation and product costing for business are discussed in section 2.1. Then behavior and forecasting of raw material prices are covered in 2.2. In the final two subsections first product costing is dealt (section 2.3) and in the last section (2.4) inventory valuation is covered.

2.1 Relevance of Inventory Valuation and Product Costing

In this subchapter some basics of management accounting are covered first. After the introduction to management accounting, significances of product costing and inventory valuation are discussed.

2.1.1 Introduction to Management Accounting

Definitions of management accounting can be found in most textbooks, and one major professional definition by Institute of Cost and Management Accountants is as follows: “the application of professional knowledge and skill in the preparation and presentation of accounting information in such a way as to assist management in the formulation of policies and in the planning and control of the operations of the undertaking” (Fanning 1983, 2). Whatever the definition is like, the basic objectives of management accounting, as Belkaoui (1980) highlights, include (1) supplying information for internal decision makers, (2) facilitating their decision making, (3) motivating their actions and behavior in a given direction and (4) promoting efficiency of organization.

Nowadays in business there are many drivers that increase the need for efficient management accounting. Especially contemporary economic environment demands excellence from corporate management accounting systems. Time-based competition exists in almost all industries, which stresses the importance of management accounting. Because of many reasons, including fluctuations in raw material prices, organization’s management accounting system must provide timely and accurate information to facilitate efforts to control costs, to measure and improve productivity and to devise improved production processes (Johnson & Kaplan 1991, 3–4). If there is an improper match between the accounting system and firm’s objectives, management can make incorrect decisions and investments (Campbell 1995).

One vital area in management accounting is product costing. Product costing affects pricing, inventory valuation and overall profit calculations heavily. That’s why the significance of product costing is covered next.

2.1.2 Product Costing Effects on Business

Product costing has major implications in running a business. Because of its importance, product costing has been researched a lot. Identifying cost drivers and developing activity-based costs is important for managerial purposes such as pricing and evaluating profitability of products and product lines (Dominiak & Louderback III 1994, 555). Keys, Balmer & Creswell (1987) argue that product costing makes designers aware of product’s potential for production and indicates potential cost reduction areas. Ostwald (1992) and Alnestig & Segerstedt (1996) argue that the most important objective of product costing is determining appropriate sales prices. Profit margin of the product is calculated based on product costs and sales price. Most profitable products are chosen, and thus product costing has major implications for product mix. (Lea & Fredendall 2002)

However, the management accounting system often fails to provide accurate product cost information. Costs are usually distributed by simplistic and arbitrary measures that do not represent the use of company’s resources. This failure to provide accurate costs for individual products may lead to misguided decisions about product pricing, product sourcing and product mix. (Johnson & Kaplan 1991, 2) If calculated product cost is not correct, whenever company’s total demand is greater than company’s production capacity, it is probable that product mix is not optimal. Sometimes even unprofitable products are manufactured due to incorrect product costs. (Lea & Fredendall 2002) By correctly choosing product costing system business performance can be clearly improved (Reinstein & Bayou 1997).

Jianxin & Tseng (1999) raise important operational problems in product costing. These include lack of accountants’ manufacturing excellence, dependence on detailed design description, lack of structured mapping between design and production and contextual heterogeneity. These problems are especially relevant in design phase. In the design phase the product structure can be changed most easily, and thus it is very relevant that the product costing is evaluated starting from the design, or even before that. (Jianxin & Tseng 1999)

Inventory valuation and product costing go hand in hand. Whenever changes in product costing are made, the effect of the changes on inventory valuation has to be considered. This relation is easily explained as follows: whenever product costs increase, inventory value decreases, and vice versa. Because of this tight relationship, when product costing is discussed, inventory valuation has to be covered too. The next chapter discusses importance of inventory valuation.

2.1.3 Importance and Challenges of Valuing Raw Material Inventory

Inventory is often the largest and most important asset that a company owns. As an asset, inventory has a direct impact on profitability of the company and especially on reporting the company's success in the balance sheet. Inventories appear on the balance sheet and the income statement under heading current assets. So, inventory valuation affects both the profitability and committed capital of the company. In each accounting period appropriate expenses must be matched with revenues in order to determine appropriate income. In inventory accounting this includes determining cost of goods sold that should be deducted from sales. That's why the net income depends directly on inventory valuation. (Hermanson, Edwards, Maher 2005, 258) Based on the direct effect on net income, inventory valuation affects cash flows. This is because taxes to be paid depend on net income. Selection of inventory valuation policy can alter cash flows due to tax obligations. (Bar-Yosef & Sen 1992)

Inventory accounting rules may also affect stockholders' wealth, because managers who are paid income-based can potentially distort inventory to maximize their payoffs. For example, if managers are paid based on return-on-equity (ROE), minimizing committed capital (including inventory) is profitable for these managers. Inventory value can be affected by the choice of inventory valuation policy without altering operations. Thus stockholders, by directly or indirectly dictating the accounting policy choice, can use accounting rules to implement their preferences and control managers. (Bar-Yosef & Sen 1992)

A major challenge in inventory valuation is volatility of raw material price and because of this volatility there are major differences between the inventory value and the budgeted value. That's why it is important to separate out total variance into planning variance and operational variance.

Planning variances seek to explain how original standards need to be adjusted in order to reflect changes in operating conditions (e.g. raw material price changes) between current situation and the time when the standard was originally calculated. In effect it means that the original standard is updated so that it is a realistic target in current conditions. Operational variances indicate the extent to which attainable targets (i.e. the adjusted standards) have been achieved. Operational variances are thus a realistic way of assessing performance. (Lucey 2003, 262–263)

There are basically two general approaches to classify cost variances for controlling purposes. First, there is an approach that classifies all variances as expenses. In this approach any savings or expenses above or below normal are abnormal. If a management sees that for control purposes inventory at cost of standard price reflects better the situation in the company, then it is reasonable to classify variances as period expenses. Second, especially for financial reporting and accounting purposes, there is an actual costing method. The variances in this method are prorated to inventories and cost of sales. (Hirsch & Louderback 1986, 354–355) The most common method to allocate variances in overhead costs is to assign those to cost of goods sold. Another way is to assign the variances in overheads to production accounts, which are work-in-progress, finished goods not sold and finished goods sold. (Hansen & Mowen 2005, 124–125)

Whatever is the method of allocating variances, the problem of variance still exists. Major part of variance is resulting from price changes. Price changes are especially important in the area of this research due to the focus on raw material inventory. Raw material prices change constantly and thus in the next chapter (2.2) aspects of modeling raw material prices are discussed.

2.2 Modeling Raw Material Price Behavior

As Johnson & Kaplan (1991, 3) mention, especially volatility of raw material prices is a challenge for management accounting. If raw material prices increase or decrease, reliability of management accounting is lowered. This makes it harder to take correct actions as the numbers in management accounting cannot be trusted. Thus an efficient method of inventory valuation and product costing needs to cope with fluctuating raw material prices. In this chapter possible forecasting models of raw material prices are covered in order to test these inventory valuation and product costing methods under volatile raw material prices.

Forecasting techniques can be divided into many dimensions. First of all, there are qualitative and quantitative techniques (Jobber & Lancaster 2003, 416–430). However, from the viewpoint of this research, the relevant techniques are quantitative. This is because the objective is to construct a simulation model, where a large number of possible price paths over several years are evaluated. It would not be possible by qualitative methods. The reasons why simulation model is constructed in this research are presented later in section 3.4.

Quantitative forecasting methods can be divided into causal and time series methods. In causal methods forecast is constructed from some other variables. (Jobber & Lancaster 2003, 420) Causal techniques are used in this research, because stainless steel prices are modeled based on nickel prices by regression analysis. Therefore regression analysis is covered in section 2.2.2. On the other hand, time-series methods are used to model nickel prices. Time series forecasting models are covered in next subchapter.

2.2.1 Time-Series Forecasting Models

Nickel is a publicly traded element. It is excavated from ground. Also in the manufacturing process there are no variables which could be used for modelling nickel prices. Therefore nickel prices are modelled by time-series models. Thus in this section possible time-series models for modelling nickel prices are covered.

There are two main goals of time series analysis: (1) identifying the nature of the phenomenon represented by the sequence of observations and (2) forecasting, which means predicting future values of the time series variable. Both of these goals require that the pattern of observed time series data is identified and more or less formally described. (StatSoft 2008) Time-series models can be divided into multiple dimensions. First concept is stationary process. If a process is strictly stationary, then the probability distribution of possible values stays the same over time. In other words, distribution of y_t is the same as of y_{t+k}, where y_t is the valued time-series variable at time t and k is an increment in time. If a process is weakly or covariance stationary, then the following three conditions must be present: (1) expected value remains same ($E(y_t) = E(y_{t+k}) = \mu$), (2) variance is constant ($\sigma^2(y_t) = \sigma^2(y_{t+k}) = \sigma^2$) and (3) autocovariance is independent of time ($Cov(y_t, y_{t+k}) =$ constant, for all k. Two types of processes often used to characterize non-stationary processes are trend-stationary process and random walk with drift. In trend-stationary process the time-series follows a certain trend. In mathematical form trend-stationary process is as follows:

(2.1) $y_t = \nu + \beta t + u_t$

where y_t is the output at time t, ν is a constant, β is the coefficient of time, t is time and u_t is the noise value (error term) at time t. (Brooks 2002, 230–231, 379–380)

Random walk with drift is a process where the next value depends on the previous value, constant drift and error term:

(2.2) $y_t = \mu + y_{t-1} + u_t$

where μ is the drift. (Brooks 2002, 380)

The simplest time-series model is moving-average process. Let u_t be independently and identically distributed random variable with expected value of 0 and variance σ^2. Then qth order moving-average is as follows:

(2.3) $y_t = \mu + u_t + \theta_1 u_{t-1} + \theta_2 u_{t-2} + ... + \theta_q u_{t-q} = \mu + \sum_{i=1}^{q} \theta_i u_{t-i} + u_t$

where y_t is the output at time t, μ is the drift, u_t is the noise value (error term) at time t, θ_i is the coefficient of noise value on lag t-i and *t* is time. (Brooks 2002, 235) Thus moving-average process is simply a linear combination of white noise processes, so that y_t depends on current and previous values of a white noise disturbance term. Let's introduce a lag operator, which is often needed to make forecasting simpler. The lag operator for moving-average process is defined as follows:

(2.4) $L^i u_t = u_{t-i}$

where L^i is the lag operator on lag i. When using the lag operator the moving-average equation gets a slightly different form:

(2.5) $y_t = \mu + \sum_{i=1}^{q} \theta_i L^i u_t + u_t$

where y_t is the output at time t, L^i is the lag operator on lag i, θ_i is the coefficient of noise value on the lag i, μ is the drift, and u_t is the noise value (error term) at time t. (Brooks 2002, 235)

A more advanced version of the moving-average is exponential smoothing. In the exponential smoothing forecasted value is constructed from values in previous periods, but by weighting the most previous values. The weight decreases by a factor of $(1-\alpha)$ period by period. Exponential smoothing is as follows:

$$(2.6) \quad y_t = \alpha \cdot y_{t-1} + \alpha \cdot (1-\alpha) \cdot y_{t-2} + \alpha \cdot (1-\alpha)^2 \cdot y_{t-3} ... = \alpha \cdot \sum_{i=1}^{\infty} \left((1-\alpha)^{i-1} \cdot y_{t-i} \right)$$

where y_t is the output at time t, α is called smoothing factor and *t* is time. (Vollmann, Berry, Whybark & Jacobs 2005, 34–36)

Another commonly known process is autoregressive process. In autoregressive process current value of y depends only on values of previous periods. In mathematical form pth order autoregressive process is expressed as follows:

$$(2.7) \quad y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} + ... + \phi_p y_{t-p} + u_t = \mu + \sum_{i=1}^{p} \phi_i y_{t-i} + u_t$$

where y_t is the output at time t, ϕ_i is the coefficient of lag i value, μ is the drift and u_t is the noise value (error term) at time t. (Brooks 2002, 235)

By using the lag operator $\boldsymbol{L^i}$ autoregressive process is as follows (Brooks 2002, 235):

$$(2.8) \quad \boldsymbol{y_t} = \mu + \sum_{\boldsymbol{i}=1}^{\boldsymbol{p}} \phi_i \boldsymbol{L^i y_t} + \boldsymbol{u_t} \quad ; \quad \boldsymbol{L^i y_t} = \boldsymbol{y_{t-i}}$$

An ARMA-process (autoregressive moving-average) is a combined model of moving-average and autoregressive processes. It states that current value of some series y depends on its previous values and combination of current and previous values of a white noise error term. ARMA(p,q)-model is algebraically as follows:

$$(2.9) \quad y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} + ... + \phi_p y_{t-p} + \theta_1 u_{t-1} + \theta_2 u_{t-2} + ... + \theta_q u_{t-q} + u_t$$

where y_t is the output at time t, ϕ_i is the coefficient of lag i value, θ_i is the coefficient of noise value on lag i, u_t is the noise value (error term) at time t, μ is the drift and *t* is time. (Brooks 2002, 249)

Previous models are developed for forecasting actual values of time-series variable. However, also volatility can vary with respect with time. For modeling volatility ARCH- (autoregressive conditionally heteroskedasticity) and GARCH-models (generalized autoregressive conditionally heteroskedasticity) can be used. ARCH and GARCH assume that variance doesn't remain constant, but it is dependent on previous error terms. The ARCH(q)-model is written as follows:

$$\text{(2.10)} \quad \sigma_t^2 = \eta_0 + \eta_1 u_{t-1}^2 + \eta_2 u_{t-2}^2 + \ldots + \eta_q u_{t-q}^2$$

where η_i is the coefficient of squared noise value at time t-i, u_t is the noise value (error term) at time t, and σ_t^2 is the variance at time t. (Brooks 2002, 446-447)

GARCH-model differs from ARCH-model in that the variance at time t is dependent also on variance of previous periods. GARCH(p,q)-model can be written as follows:

$$\text{(2.11)} \quad \sigma_t^2 = \eta_0 + \eta_1 u_{t-1}^2 + \eta_2 u_{t-2}^2 + \ldots + \eta_q u_{t-q}^2 + \kappa_1 \sigma_{t-1}^2 + \kappa_2 \sigma_{t-2}^2 + \ldots + \kappa_p \sigma_{t-p}^2$$

where κ_i is the coefficient of variance at time t-i. (Brooks 2002, 453-454)

Bera & Higgins (1993) mention the following advantages of using ARCH-model: (1) ARCH-models are simple and easy to handle, (2) ARCH-models take care of clustered errors, (3) ARCH-models take care of nonlinearities and (4) ARCH-models take into account changes in the econometrician's ability to forecast.

The goodness of time-series forecasting model can be measured by many different methods, each measuring the forecast at least slightly differently. First of all, forecasting error is defined as the difference between the realized value $\boldsymbol{y_t}$ and the forecasted value f_t: $\boldsymbol{u_t} = \boldsymbol{y_t} - \boldsymbol{f_t}$. This error term has a major role in the measures of goodness. Mean absolute percentage error (MAPE) measures average absolute percentage error in the forecast and is defined as follows (Lewis 1982, 37, 40):

(2.12) $$\boldsymbol{MAPE} = \frac{1}{\boldsymbol{n}}\sum_{\boldsymbol{t}=0}^{\boldsymbol{n}-1}\frac{|\boldsymbol{u_t}|}{\boldsymbol{y_t}}\cdot 100$$

where u_t is the error term at time t, $\boldsymbol{y_t}$ is the realized value at time t and n is the number of observations. Typically MAPE under 10 % implies highly accurate forecasting. The strength of MAPE is that it tells the average error compared to the value forecasted. By mean percentage error (MPE) possible bias can be determined. MPE is the same as MAPE in all other respects but the error term is not an absolute value:

(2.13) $$\boldsymbol{MPE} = \frac{1}{\boldsymbol{n}}\sum_{\boldsymbol{t}=0}^{\boldsymbol{n}-1}\frac{\boldsymbol{u_t}}{\boldsymbol{y_t}}\cdot 100$$

However, the most used measure when the optimal forecasting models are being sought is the sum of the squared errors (SSE). It is defined as the sum of error squares:

(2.14) $$SSE = \sum_{t=0}^{n-1} u_t^2$$

Also mean squared error is common and it is defined as follows:

(2.15) $$\boldsymbol{MSE} = \frac{1}{\boldsymbol{n}}\sum_{\boldsymbol{t}=0}^{\boldsymbol{n}-1}\boldsymbol{u_t}^2$$

where $\boldsymbol{u_t}$ is the error term at time t and $\boldsymbol{n}$ is the number of observations. (Lewis 1982, 40–41)

2.2.2 Regression Analysis

In this section an often used quantitative data analysis method, regression analysis, is covered. Regression analysis in this research is vital, because stainless steel prices are dependent on other variables. By regression analysis this dependence can be tested and significant variables defined. Also, by regression analysis the mathematical model underlying between stainless steel prices and these variables can be found and used in simulation model built in empirical part of this research. The objective of this analysis is to give a brief but still a holistic view of regression analysis. The main areas considered in this chapter are when it should be used, what the main mathematical considerations are and what potential flaws in using regression analysis are.

Regression analysis answers questions about dependence of a dependent variable on one or more predictors (Weisberg 2005, xii). Malhotra & Birks (2006, 581) recognize five different uses for regression analysis: (1) testing whether there exists a specific relationship between independent variables and dependent variable, (2) determining the strength of the relationship between these variables, (3) determining mathematical equation relating independent variables and dependent variable, (4) predicting values of the dependent variable and (5) controlling other independent variables when evaluating contributions of a specific set of variables. Montgomery & Beck (1992, 5) identify one additional use for regression analysis, which is data description.

Linear regression analysis can be divided into simple and multiple regression analysis. In simple regression analysis there is only one independent variable and in multiple regression analysis there are two or more. In this research multiple regression analysis is used because it is assumed that there are several variables affecting stainless steel prices. Mathematically multiple linear regression analysis is as follows:

$$(2.16)\quad y = c_0 + c_1x_1 + c_2x_2 + \ldots + c_nx_n + \varepsilon$$

where x_i is the value of an independent variable i, y is the value of the dependent variable, c_i are the parameters ($\boldsymbol{c}_0$ is intercept) and ε is the error term. (Neter, Wasserman & Kutter 1990, 31, 229) In regression analysis parameters c_i are estimated. These parameters are often estimated using ordinary least squares estimators, which means that the parameters minimize the sum of error squares (SSE). The sum of squared error terms is as follows:

$$(2.17)\quad SSE = \sum (y_i - \hat{y}_i)^2$$

where y_i is the value of dependent variable and $\hat{y}_i$ is the estimated value of the dependent variable. There is also another kind of variation, which is regression sum of squares (RSS). It is algebraically as follows:

$$(2.18)\quad RSS = \sum (\hat{y}_i - \bar{y})^2$$

where $\hat{y}_i$ is the estimated value of dependent variable y_i and $\bar{y}$ is the average of all values of the dependent variable y_i. Total variation is measured using total sum of squares (TSS); it includes both variation due to errors and regression:

$$(2.19)\quad TSS = \sum (y_i - \bar{y})^2$$

where y_i is the value of the dependent variable and $\bar{y}$ is the average of all values of the dependent variable y_i. (Lewis-Beck 1995, 47–48)

Even though the previous sums of squares are important, from those the goodness of regression model cannot be determined. A leading measure for evaluating goodness of regression model is coefficient of determination (R^2). The coefficient of determination is mathematically derived from the sums of squares as follows:

$$(2.20)\quad R^2 = \frac{RSS}{TSS} = \frac{1 - ESS}{TSS}$$

where *RSS* is the regression, *ESS* the error and *TSS* the total sum of squared errors. When regression accounts of all the variation, $R^2 = 1$, and when the regression explains no variation, $R^2 = 0$. Usually R^2 fall between these two. (Lewis-Beck 1995, 47–48)

In regression analysis there are five main limitations. First of these states that the expected value of error term ε_i (see equation (2.16) should be 0 for all observations, algebraically $E(\varepsilon_i)=0$ for all i. This condition is assumed if the intercept $\boldsymbol{c}_0$ is included in the regression equation. Second of the limitations states that variance of the error term is constant for all observations, algebraically $\sigma_{\varepsilon_i} = \sigma_\varepsilon$ for all i. This condition is also known as homoscedasticity. If heteroscedasticity exists, then estimators will be inefficient, which means that variance of the estimators is not smallest possible. Third limitation is that error terms should not be correlated. Mathematically it means that covariance between error terms should be 0: $\sigma_{\varepsilon_i \varepsilon_j} = 0$ (i≠j). If this condition is not present, then estimators are inefficient. Fourth limitation assumes that error term is distributed independently of independent variables, algebraically $\sigma_{x_i \varepsilon_i} = 0$. The last limitation is that the error term should be normally distributed. (Dougherty 2002, 77–79)

There are several abuses of regression analysis that can be made. Three common misapplications are extrapolation, generalization and causation. Extrapolation of data means predicting values of dependent variable with values of independent variables that are not in the range of data. Generalization occurs when researcher is trying to use results of regression analysis from a body of data to make inferences for another body of data. The danger here is that the two bodies of data might not possess the same characteristics. The reason for generalization being improper is that there are extraneous factors affecting the dependent variable that regression analysis doesn't cover. Causation as an abuse of regression analysis exists when researcher concludes that a dependent variable is explained by an independent variable, even though the correlation is due to some other variables. (Gunst & Mason 1980; 12–18) This causation is a major problem in scientific publications according to Ferson, Sarkissian & Simin (2003), as they argue that many of the regressions in literature may be spurious. By spurious regression is meant that correlated variables are used to explain some variable, even though there is no causation.

Berry & Feldman (1985, 18, 26, 37, 51) recognize also other abuses, or rather causes of abuses in regression analysis. These are specification error, measurement error, multicollinearity, non-additivity and non-linearity. Specification error occurs when a researcher assumes a specific incorrect relationship between the independent variables and the dependent variable. Measurement error can be divided into random and nonrandom parts. Random measurement error is just unsystematic noise in the variables. Nonrandom measurement error occurs if researcher is in some degree systematically measuring some variable wrong. (Berry & Feldman 1985, 18, 26)

Multicollinearity is a statistical phenomenon in which two or more independent variables in a multiple regression model are highly correlated. Multicollinearity increases standard error of estimates, and thus reduces degree of confidence. However, it does not result in biased estimates. (Sykes 1999) Multicollinearity as a problem depends on the use of regression analysis. If researcher uses regression analysis to predict values, multicollinearity is of a little problem. However, if regression analysis is used for explanation, then multicollinearity might be of a serious problem. (Berry & Feldman 1985, 40–41)

Regression analysis is based on additivity and linearity characteristics. The best way to detect non-additivity and non-linearity is to compare the model to the theory underlying the model. If linear model is not adequate, then there are two common options. In first, the linear model is replaced by some other model, such as polynomial model or exponential model. (Berry & Feldman 1985, 53, 57, 60) On the second option the independent variable used in the regression model can be a function of the value of the original independent variable. For example, $\log X$ can be used instead of X. (Farnum & Stanton 1989, 251)

2.3 Product Costing

In this subchapter different aspects of product costing are discussed, because they are important in order to recognize what the best perspective in product costing is. For example, the choice between full and variable costing can have major impact on business performance as will be observed in the following. Whether full or variable costing is chosen, method of costing still needs to be determined. Costing methods are based, for example, on market prices or marginal costs. In this chapter actual methods of calculating product costs are discussed too. These methods of calculating product costs include, for example, theory of constraints (TOC) accounting and activity-based costing (ABC). Different methods calculate product costs differently and are applicable in different situations, and thus these methods are needed to be considered in order to find out the best method suited to the situation at hand.

2.3.1 Different Aspects of Product Costing

The objective of product costing is to set costs as near as possible to real costs of products. However, for example, due to lack of data, this is seldom possible. Also real costs itself is a theoretical concept. There are various errors associated with product costing. First, specification error arises when the method used to identify costs to products does not reflect demands placed on the resources by individual products. For example, if a product really needs one unit of resource A, but in the product costing it has been allocated two units of the resource, there is a specification error. (Datar & Gupta 1994) Manufacturing a product requires resources that do not vary directly with the volume (e.g. setups). Aggregation errors occur when costs and units of a resource are aggregated over heterogeneous activities to derive a single cost allocation rate. (Foster & Gupta 1990) Specification and aggregation errors increase demand for more refined costing systems. But there is a drawback in the modern accounting systems; the measurement costs are increased. So there is a tradeoff between exactness of product costing and costs of measurement. (Datar & Gupta 1994)

Product costs can be divided into many dimensions. First of all, there are fixed and variable costs. Fixed costs are costs that are independent of amount of resources used and variable costs depend linearly on the amount of resources used. The so-called traditional cost accounting literature often suggests that product costing should be based on variable costing, because it offers more usable and flexible information for decision-making than full costing (Lukka & Granlund 1996). Full cost is the sum of allocated fixed costs and variable costs. Major weakness of the full costing is that full costs lead user department to evaluate the full cost and benefit rather than marginal cost and benefit. (Miller & Buckman 1987) Full costing also often considers historical sunk costs rather than the future outlay of costs (McLaney & Atrill 1999, 312). Variable costing has the desired property that operating departments are encouraged to expand their use until marginal cost exceeds marginal benefit (Miller & Buckman 1987). As Fanning (1983, 167) confirms, maximum profit will be earned where marginal revenue is equal to marginal cost. However, there exists some critique towards variable costing. Zimmerman (1979) argues that variable costing may form delays and rationing costs on other users within the company. So, allocating also fixed costs according to actual usage may be desired since these allocated costs can serve as a useful estimation for opportunity costs, which are difficult to observe due to delay and rationing (Zimmerman 1979). Also full costing provides long-run relevant costs (McLaney & Atrill 1999, 312). In Finnish companies fixed costs are around 30 percent according to Lukka & Granlund (1994) (Figure 2-1). Thus choosing full or variable costing has a real significance.

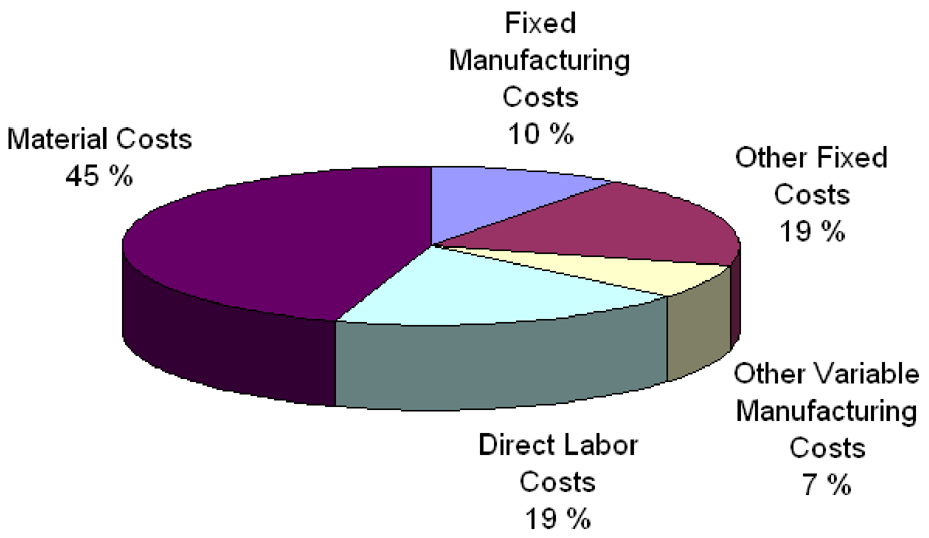

Figure 2-1 - Typical cost structure of a Finnish manufacturing unit (Lukka & Granlund 1994)

Bierman Jr. (1959) presents three methods to determine intracompany transfer price, which can be considered as substitutes for product costing. The methods are based on marginal cost, market price and negotiated price. The marginal cost is nearly the same as variable cost method and the variable cost method is often used instead of marginal cost method because it is difficult to determine the marginal cost curve. (Bierman Jr. 1959) In the market price method the product costs are determined by the corresponding market prices. Market prices are generally recommended if there exists one market price and market is competitive. Management cannot easily manipulate market prices, and thus it is an efficient costing method. However, ascertaining market prices is not always as easy as might appear. It is more difficult to use market prices because of several factors, such as ensuring product compability, taking into account handling and distribution costs, obtaining up-to-date market prices and making sure that there is a ready access to external market without damaging side effects. (Fanning 1983, 389) Dean (1955) suggested that each division of a firm is an independent profit centre and divisional managers should determine the transfer prices through negotiation. Then there should be free access to all data in market and buyers and sellers should be free to deal in external markets. However, this negotiation procedure is expensive and time-consuming and can cause tension between correspondents. A common practice is also some assessment of cost augmented by a mark-up. The actual mark-up will probably be determined by custom, and its impact on divisional performance will be hazardous and haphazard. Such allocation procedure does not provide guidelines for efficient allocation of resources between divisions. (Fanning 1983, 388–389) According to Fanning (1983, 387) transfer price method should depend at least on the following factors: existence of an external market price for product, market structure in which company operates and degree of interdependence between divisions.

2.3.2 Methods of Calculating Product Costs

The previously discussed different aspects of product costing do not provide exact information on how to calculate the product costs in different methods. Now the methods of calculating product costs are covered.

The ways of calculating product cost structure include theory of constraints accounting (TOC) and activity based costing (ABC). They both represent alternative paradigms. Principle of TOC assumes that every organization has a constraint or bottleneck that restricts its performance. In TOC accounting performance of the company is improved by efficiently organizing this bottleneck because TOC takes into account the use of constraints in forming product costs. (Kee & Schmidt 2000) The benefits of TOC are as follows: (1) increasing revenue by increasing the volume of production, (2) reducing cost per unit through increasing the production overall by maximizing efficiency of the bottleneck, (3) management's time is allocated to the area that needs the most attention, which is often the bottleneck (Mekong Capital 2005). Firms that have adopted TOC confirm that it has aided in reducing lead-time, cycle time and inventory, while improving productivity and quality (Jayson 1987).

Activity based costing (ABC) system models causal relationship between products and resources used in their production. ABC identifies activities that compose overhead costs and charges each product for the quantity of each activity it consumed. The advantage of ABC is that it provides more accurate information of product costs for evaluating the profitability of the company's product lines and customer base. (Kee & Schmidt 2000) According to Cooper & Kaplan (1991, 130) management can thus analyze how products, brands, customers, facilities, regions and distribution channels generate revenues and consume processes.

Traditional accounting system allocates overheads to product costs using volume-sensitive cost drivers, such as direct labor (Kee & Schmidt 2000). Traditional costing is seen to be inconsistent with today's manufacturing methods (e.g. Monden & Lee 1993; Ferrara 1995). This is because traditional costing is not able to provide appropriate strategic signals for business enterprises (Fleischman and Tyson 1998). It may lead to dysfunctional behavior, for example, by encouraging bulk purchasing, which leads to high inventories (Lucas 1997). However, standard costing is still in common use even in very developed countries, such as Japan (Sulaiman, Ahmad & Alwi 2006).

There is no single method recommended to be used in all situations; on the contrary, the choice of method should depend on overall situation (Kee & Schmidt 2000). Some researchers argue that TOC should be used for short-term planning and ABC for long-term planning (Lea & Fredendall 2002). Lea's (1998) study indicated that TOC did not perform adequately when there were significant overheads, labor costs and automation involved in the manufacturing process. Campbell, Brewer and Mills (1997) recommended TOC for machine-intensive departments because costs of these departments are formed from creating and maintaining long-term capacity. In machine-intensive departments allocation of fixed costs to products is not appropriate because in managing constant resources time is a relevant measure, not money (Campbell, et al. 1997). When product mix decision is considered, Kee & Schmidt (2000) argue that relative performance of TOC and ABC accounting depend on the extent of management's control over labor and overhead.

Traditional costing system can underestimate costs of low volume products that have many levels in bill-of-material and require many supporting activities. It can consequently allocate too large a percentage of overhead costs to a high volume product with a flat bill-of-material. (Johnson, 1991; O'Guin, 1991) TOC ignores product structure and does not attempt to allocate support function costs to products. So, TOC may avoid cost distortions related to allocating overheads, but it may create another type of cost distortion if a product has low raw material costs and a high sales price, but requires intensive support and technology investment. ABC might provide more accurate product costs when products differ in their breadth and depth since ABC tracks all activities used by all components of each product and charges the products only for activities that were consumed. (Lea & Fredendall 2002) However, the main disadvantage of ABC costing is the difficulty of obtaining accurate information to determine proper allocations (Hundal 1997). It has also been argued that ABC requires detailed activity analysis, and thus if ABC is implemented there is a significant need of changes in cost accounting systems (Sheldon, Huang & Perks 1991).

Theory of product costing has now been covered. As was mentioned previously, inventory valuation is highly related to product costing. In the next section different inventory valuation methods are analyzed.

2.4 Inventory Valuation Methods

Determining inventory valuation method that best fits to the circumstances faced is essential. Tax shield benefits can be huge and precision of management accounting measures can be improved much by just choosing appropriate inventory valuation method. So recognizing possible methods to value inventory and analyzing those is needed if the current inventory valuation is to be improved.

There are basically four GAAP cost flow assumptions: (1) specific identification; (2) first-in, first-out (FIFO); (3) last-in, first-out (LIFO); and (4) weighted average cost (Wilson & Walter 2003). GAAP (Generally Accepted Accounting Principles) is the common set of accounting principles, standards and procedures that companies use to compile their financial statements. These four methods are now introduced and briefly analyzed one at a time. After that some other possibilities for inventory valuation methods are presented. In the final part these methods are compared with each other and optimal methods in different situations are analyzed.

2.4.1 Specific identification

Specific identification method requires matching each item sold with its actual costs. Items in inventory are specifically set to cost the total costs of ending inventory (Simple Studies 2007). It is a simple and workable method for businesses selling a few high priced items such as cars or jewelry, but it is not practical when tracking high volume, low priced items such as units of crude oil or natural gas (Wilson & Walter 2003). The challenge in raw material or other high volume material accounting is to keep track of different purchase prices, which is not convenient in specific identification (Simple Studies 2007). As an example, Amazon, having a high volume but also some one-of-a-kind business, values inventory by using specific identification (Pollard, Mills & Harrison 2007, 411).

The main advantage of specific identification is that it provides good matching between costs and revenues. Some accountants argue that specific identification is the most precise accounting method in matching the costs and revenues, and therefore it is theoretically the soundest method. This statement is true for any one-of-a-kind items, and for these items any other accounting method would seem illogical. (Hermanson et al. 2005, 273)

However, specific identification has its disadvantages. One of the main disadvantages, even concerning one-of-a-kind items, is the possibility of manipulation. For example, if a company would buy two identical items with different prices from supplier, there needs to be chosen which one of the items is sold first to a customer. A manager optimizing his own utility will choose as he prefers, and this can distort financial statements. For example, if a car dealer has two identical cars with different costs, profit of the sale for those cars would be different, even though the cars are identical. (Hermanson et al. 2005, 273; Simple Studies 2007)

2.4.2 First-In First-Out

In FIFO it is assumed that inventory in hand includes the items last purchased (Wilson & Walter 2003). For example, consider the following situation. A company has an opening inventory of 100 items and the inventory value is 100€, 1€ per an item. If in the current period company buys 100 items at the price of 2€, but sells 80 items, inventory by FIFO method is valued at (100-80)*1€+100*2€=220€. The inventory for valuation purposes includes 20 items from the initial inventory and all the 100 items bought in the current period.

FIFO has four major advantages: (1) it is easy to apply, (2) the flow of costs corresponds with the physical flow of goods, (3) there is no possibility of manipulation and (4) amount of inventory in balance sheet is likely to be approximately market value. All these advantages are due to the fact that when a company sells goods, the costs removed from the inventory are the oldest units when inventory valuation is considered. Company or manager cannot manipulate figures by pure accounting tricks because the costs removed are not determined by a serial number. (Hermanson et al. 2005, 273) The easiness in adaptation is also essential. In FIFO the reports are ready fast and thus making decisions based on inventory is faster (Francis 2001). Only the FIFO method is in line with the recommended way in which the materials should be physically issued. All other methods are purely methods of pricing. (Chadwick 2002, 196)

The two main disadvantages of FIFO are (1) recognition of paper profits and (2) heavier tax burden under inflation (Hermanson et al. 2005, 273). By paper profits it is meant the difference between the costs of a replacement unit and the historical cost of the unit. For example, say a company has three identical items in inventory in order of purchase time purchase prices being 1€, 2€ and 4€. FIFO would allocate a cost of 1€ to the next sale and LIFO a cost of 4€. LIFO is covered in next chapter. The difference of 4€-1€=3€ represents paper profits in FIFO compared to LIFO. The heavier tax burden under inflation results from the fact that the inventory in hand includes the last purchases, which are the most valuable. Thus in net income calculation costs allocated to sales are the least valuable, which increases profits and thus tax obligations. (Wilson & Walter 2003)

2.4.3 Last-In First-Out

In LIFO inventory in hand includes the first purchases (Wilson & Walter 2003). Let’s consider the same example as in the beginning of section 2.4.2. In LIFO inventory value is 100*1€+(100-80)*2€=140€, which is quite different from value by FIFO method (220€).

LIFO has several advantages, which are based on the fact that prices have risen almost constantly for decades. LIFO supporters argue that this upward trend in prices leads to paper profits under FIFO, thus making LIFO more appealing. (Hermanson et al. 2005, 273) Opposite to FIFO, LIFO also brings tax benefits under inflation (Pollard et al. 2007, 413). Another advantage of LIFO is that the costs allocated to products are the most recent and reflect reality. By LIFO, company performance can better be evaluated, because the cost of goods sold and thus net income is based on the current situation. (Hermanson et al. 2005, 274) Due to the reflection of reality, writing down of inventory to market price is minimized (Robertson & Clark 2004).

Disadvantages of LIFO according to FIFO supporters include the following: (1) LIFO doesn’t reflect physical flow of goods, (2) LIFO understates inventory and (3) LIFO permits income manipulation. There is a continuous debate on whether physical and cost flow should reflect each other. The second criticism is valid under rising prices, especially if inventory in LIFO includes items several periods ago. Income manipulation criticism is also valid. For example, if it is assumed that management wishes to reduce income, the company purchases an abnormal amount of items at the end of the previous period, whereby the costs of goods in the next period are high. Vice versa, management could delay purchases to increase income. (Hermanson et al. 2005, 274) Robertson & Clark (2004) mention also that LIFO may cause poor buying habits because of layer liquidation problem. This layer liquidation problem exists because in LIFO there are goods from different periods and thus the goods have different values. Sometimes management may want to allocate specific costs to products, and therefore it won't purchase as efficiently as possible. Sometimes this inefficiency in purchasing outweighs tax benefits (Bar-Yosef & Sen 1992).

2.4.4 Weighted Average Cost

In the weighted average cost method inventory is appreciated by using the amount of inventory before current period and the purchase price and the amount in current period:

$$(2.21)\quad WAC(t) = \frac{WAC(t-1)\cdot Inv(t-1) + pup(t)\cdot pu(t)}{Inv(t)}$$

where $WAC(t)$ is the weighted average cost at time t, *Inv(t)* is the inventory in units at time t, *pup(t)* is the purchase price at time t, *pu(t)* is the purchases at time t and *t* is time in periods (Chadwick 2002, 194). When the example in the beginning of section 2.4.2 is considered, inventory is calculated as follows: weighted average cost before the sales is $\frac{100\cdot 1€ + 100\cdot 2€}{200} = 1{,}5€$ and inventory value 1,5€*200=300€. So the inventory value after the sales is 300€-1,5€*80=180€.

However, there are a number of variations of the weighted average cost method. For example, the weighted average cost can be divided into continuously updating and periodical review. In the continuous updating weighted average cost is updated after every purchase. On the contrary, in the periodical review weighted average cost is updated at the end of every period. (Chadwick 2002, 1994)

Weighted average cost method has a singular advantage of not needing a database that itemizes many potential layers of inventory at different costs by which they were acquired (Bragg 2005, 119–120). By this Bragg (2005, 119–120) means that in weighted average cost method only the latest weighted average cost is needed to calculate cost flow out. In other considerations weighted average cost method falls between FIFO and LIFO. Inventory value is not as up-to-date as in FIFO, but is a better approximation than in LIFO. When considering costs of goods sold and tax advantages weighted average cost method is again between LIFO and FIFO. (Hermanson et al.

2005, 274) Wilson and Walter (2003) argue that weighted average cost method is attractive, because it brings some of the benefits associated with LIFO and has the simplicity associated with FIFO. Weighted average cost method is worth investigating especially when physical flow of inventory is difficult to measure and when inventory is relatively homogenous. (Wilson & Walter 2003)

Because the case company of this research uses weighted average cost method for reporting purposes, WAC is considered here more thoroughly. Now the weighted average cost is derived mathematically. First of all, inventory value in the beginning of the previous period is simply the inventory in kilograms multiplied by previous weighted cost of capital:

$$(2.22)\quad Iva(t-1) = Inv(t-1) \cdot WAC(t-1)$$

where *Iva(t-1)* is inventory value at time t-1, *Inv(t-1)* is inventory in kilograms at time t-1, $WAC(t-1)$ is weighted average cost at time t-1 and *t* is time in periods. Purchases at a specific day i are valued as purchases in kilograms multiplied by the current price: $pu(i) \cdot pup(i)$. So total purchases in period t are as follows: $\left[\sum pu(i) \cdot pup(i)\right]_t$. These total purchases are later referred to as *pur(t)*. However, sales are priced based on the final WAC of the period. So the sales at period t are total sales in kilograms at the period (*S(t)*) multiplied by weighted average cost at the end of the period: $S(t) \cdot WAC(t)$. So the accounted inventory at the end of the period is the initial inventory plus purchases minus sales:

$$(2.23)\quad Iva(t) = Inv(t-1) \cdot WAC(t-1) + pur(t) - S(t) \cdot WAC(t)$$

New weighted average cost is the inventory divided by inventory in kilograms and is as follows:

$$(2.24)\quad WAC(t) = \frac{Iva(t)}{Inv(t)} = \frac{Inv(t-1) \cdot WAC(t-1) + pur(t) - S(t) \cdot WAC(t)}{Inv(t)}$$

In the previous equation there are $WAC(t)$ in both sides. $WAC(t)$ can be solved as function of $WAC(t-1)$ as follows:

$$(2.25)\quad WAC(t) = \frac{Inv(t-1) \cdot WAC(t-1) + pur(t)}{Inv(t) + S(t)}$$

where *Inv(t)* is the inventory in kilograms at time t, *WAC(t)* is the weighted average cost at time t, *pur(t)* is the purchases in euros in period t, *S(t)* is the sales in kilograms in period t and *t* is time in periods.

This equation (2.25) is independent of time and thus the same equation can be modified for $WAC(t-1)$. This $WAC(t-1)$ can be placed to equation (2.25):

$$(2.26)\quad WAC(t)=\frac{Inv(t-1)\cdot\dfrac{Inv(t-2)\cdot WAC(t-2)+pur(t-1)}{Inv(t-1)+S(t-1)}+pur(t)}{Inv(t)+S(t)}$$

$$=\frac{\dfrac{Inv(t-1)}{Inv(t-1)+S(t-1)}\cdot Inv(t-2)\cdot WAC(t-2)+\dfrac{Inv(t-1)}{Inv(t-1)+S(t-1)}\cdot pur(t-1)+pur(t)}{Inv(t)+S(t)}$$

And the same can be done for $WAC(t-2)$. This process can be done until initial $WAC(0)$ is attained:

$$(2.27)\quad \boldsymbol{WAC}=\frac{\boldsymbol{pur(t)}+\dfrac{\boldsymbol{Inv(t-1)}}{\boldsymbol{Inv(t-1)+S(t-1)}}\cdot\boldsymbol{pur(t-1)}+\ldots+\dfrac{\boldsymbol{Inv(t-1)}}{\boldsymbol{Inv(t-1)+S(t-1)}}\cdot\dfrac{\boldsymbol{Inv(t-2)}}{\boldsymbol{Inv(t-2)+S(t-2)}}\cdots\dfrac{\boldsymbol{Inv(1)}}{\boldsymbol{Inv(1)+S(1)}}\cdot\boldsymbol{pur(1)}}{\boldsymbol{Inv(t)+S(t)}}$$

where *Inv(t)* is the inventory in kilograms at time t, *WAC(t)* is the weighted average cost at time t, *pur(t)* is the purchases in euros in period t, *S(t)* is the sales in kilograms in period t and *t* is time in periods.

Inventory value is calculated by multiplying WAC with current inventory level:

$$(2.28)\quad Iva(t)=\frac{Inv(t)}{Inv(t)+S(t)}\left[pur(t)+\frac{Inv(t-1)}{Inv(t-1)+S(t-1)}pur(t-1)+\ldots+\frac{Inv(t-1)}{Inv(t-1)+S(t-1)}\cdot\frac{Inv(t-2)}{Inv(t-2)+S(t-2)}\cdots\frac{Inv(1)}{Inv(1)+S(1)}\cdot pur(1)\right]$$

The conclusion is that purchases from way past are affecting weighted average cost and inventory value, especially when sales compared to inventory are small. As a result of that WAC is updating very slowly, and when raw material prices are volatile, inventory value can be far from market value. On the other hand, if the inventory is small and inventory turnover high, WAC is highly dependent on the near past purchase prices.

If sales are a constant fraction of inventory, WAC equation gets a slightly different form:

(2.29) $$WAC_t = \frac{pur(t) + \frac{1}{1+a} \cdot pur(t-1) + \frac{1}{(1+a)^2} pur(t-2) + ... + \frac{1}{(1+a)^{t-1}} \cdot pur(1)}{(1+a) \cdot Inv(t)}$$

$$= \frac{\frac{1}{1+a} pur(t) + \frac{1}{(1+a)^2} \cdot pur(t-1) + \frac{1}{(1+a)^3} pur(t-2) + ... + \frac{1}{(1+a)^t} \cdot pur(1)}{Inv(t)}$$

And inventory value is as follows:

(2.30) $$Iva(t) = \frac{1}{1+a} pur(t) + \frac{1}{(1+a)^2} \cdot pur(t-1) + \frac{1}{(1+a)^3} pur(t-2) + ... + \frac{1}{(1+a)^t} \cdot pur(1)$$

where *Iva(t)* is the inventory value at time t, a is the sales-inventory-ratio, *pur(t)* is the purchases in euros at time t and *t* is time in periods. From the equation it is readily evident that the past values are stressed if inventory is large compared to sales, in other words, when the inventory turnover is low.

FIFO, LIFO and weighted average cost are often used in financial accounting of petroleum. (Wilson & Walter 2003) So, when considering possible inventory valuation method alternatives for the case company, FIFO, LIFO and weighted average cost might be possible options.

2.4.5 Other Methods for Inventory Valuation

The four methods described previously are cost methods. Cost methods are based on the historical cost principle which suggests that inventory and other assets should not be reported above their cost to consolidated entity (Jeter & Chaney 2007, 301). However, alongside with the cost methods there has evolved a concept of market method. In the market method inventory is valued on the basis of the current market price, and thus it can be very different compared to the cost methods. Many accountants recommend the market price to be generally used when valuing inventory and marketable securities (Bierman Jr. 1967). A combination of the cost method and the market prices, a method known as lower-of-cost-or-market, values inventory on the basis of market value or costs, whichever is lower. In lower-of-cost-or-market method a company is required to recognize an additional expense in its cost of goods sold if replacement cost has declined below its carrying cost. However, if market value of inventory subsequently rises back to or above carrying cost, recorded value cannot be increased back to the original amount. (Bragg 2005, 123) The advantage of the lower-of-cost-or-market method is that company is able to defer some taxes for later periods if prices of goods decrease.

Neilimo & Uusi-Rauva (2005) mention two additional methods for inventory cost accounting. These are price of the day and standard price. In the price of the day method cost flow out of inventory is determined by the latest purchase price. This method is thus quite near the market price method, but it uses previous purchase as a determinant, which can be several days or months old. In standard price method cost flow is determined by a single standard price, which should reflect the market price. The price is determined from long-term development of prices. Especially in different scenario modeling standard price provides good guess for cost flow. (Neilimo & Uusi-Rauva 2005, 93) Fry, Steele & Saladin (1996) propose that standard cost system is applicable when direct costs, specifically labor, represent a large percentage of total manufacturing costs. Standard cost is not appropriate when overhead costs from a major share of total costs or when labor costs are relatively small (Fry, Steele & Saladin 1996).

By the previous analysis of inventory valuation methods it is not possible to choose the best method in different situations and that is why in the next subsection inventory valuation methods are compared based on previous analysis and literature.

2.4.6 Comparison of Inventory Valuation Methods

After getting familiar with the inventory valuation methods, it is important to compare these methods with each other. First, the advantages and disadvantages of FIFO, LIFO and weighted average cost method brought up in the previous subsections are analyzed. After that the factors that should be taken into account when choosing an inventory valuation method are summarized.

One consideration in choosing the inventory valuation methods is implementation. Previously it was mentioned that FIFO is easy to apply. This is partly because in FIFO there are not so much layers in use as is in LIFO. The layers mean items having different prices, and thus they need to be considered separately. LIFO may have several layers in use at the same time when the material in inventory is far away from past, and thus that has to be considered in inventory calculations. In the weighted average cost method inventory calculations are the simplest, because new weighted average cost and inventory value depend only on the previous inventory and the latest sales and purchases. So, if inventories are complex, a simple method to implement should be considered, and then weighted average cost is most attractive.

Another consideration is the trade-off between accuracy of product costing and accuracy of inventory value. When compared with market value, product costing is most accurate in LIFO, because the latest inventory is allocated to product costs. In FIFO inventory allocated to product costs can be relatively far from past and if prices have changed a lot product costing is not near market prices. So if a company uses pricing based on product costs, LIFO would be the most efficient. But the downside using LIFO in this sense is that the inventory value does not correspond to the market value. Because the latest inventory is allocated to the sales in LIFO, remaining inventory includes products from way past and value of these does not reflect market prices if prices have changed a lot. In FIFO situation is the opposite.

It is also possible to manipulate figures in LIFO. This is because there are layers in inventory. In FIFO this is not possible and in WAC it is difficult, thus if this kind of behavior would be expected, FIFO or WAC should be chosen.

When raw materials are considered, it is common that prices have a relatively high volatility and there is often a trend how the prices are changing. Because inflation exists nearly everywhere, the trend is upward. So it is reasonable to evaluate the methods based on what happens if the prices change. In the following table (Table 2-1) there is a comparison of FIFO, LIFO and weighted average cost. As it is readily observed, when the prices rise LIFO is an attractive choice. (Financial education 2008) This upward trend exists often with stainless steel prices which are discussed later in this research.

Table 2-1 - Inventory accounting methods in the case of inflation (Financial education 2008)

Method	***Assumption***	***Income Statement Effect***	***Balance Sheet Effect***
FIFO	When company sells an item from inventory, the oldest one is sold	The older inventory was cheaper, so cost of sales is less and income is higher	The remaining inventory carried on the balance sheet is the newest, and most valuable
LIFO	When an item is sold from inventory, the newest one is sold	The newer (more expensive) inventory is sold, so the cost of sales is higher and income is lower	Remaining inventory is shown as an older and less valuable asset
Weighted average cost	The average cost of all inventory is used for both cost of sales and inventory	Both cost of sales and income will be between the levels recorded in LIFO and FIFO	Inventory asset will be between the levels recorded in LIFO and FIFO

In the 1970s hundreds of firms changed inventory valuation method to LIFO in response to high rates of inflation. However, many still continued with FIFO method. (Lee & Hsieh 1985) Biddle (1980) estimated that 105 firms investigated in his study paid an average of nearly $26 millions in additional federal income tax. So there is something else than the potential tax benefits that make firms to decide their inventory accounting policy. According to Lee & Hsieh (1985), the choice of inventory accounting method is affected in addition to tax shield benefits by three factors: political costs, agency costs and divergent production and investment characteristics. According to Bar-Yosef & Sen (1992) an optimal accounting policy takes into account this distortion (the incentive effect) as well as tax gains possible with LIFO. Whatever the choice of inventory valuation method, switching is not easy and not easily reversed, especially in the case of LIFO (Lee & Petruzzi 1989).

Potential determinants on decision of corporate inventory accounting according to Hunt (1985) include the following two: (1) restrictive debt covenants and (2) the extent of managers being owners. The restrictive debt covenants include restriction of dividend payments, asset maintenance restrictions such as minimum working capital and restriction of financing policy (e.g. increasing debt-equity-ratio) (Hunt 1985). Inventory affects these restrictions clearly. If inventory value is low, working capital is lower and minimum working capital limit might be in danger. When the limit of working capital is near and inflation exists, LIFO method can be harmful because it values the inventory on the basis of the oldest items, which are valued the lowest under inflation. Thus FIFO or weighted average cost method should be preferred. The extent to which managers are owners affects the choice of the method. If the ownership is high, management can choose the best method for their purposes. Therefore, if management compensation is dependent on the income, the managers prefer income-increasing methods. (Kuo 1993) Niehaus (1989) argues that if managerial ownership is low, management can exercise little discretion in choosing the method. LIFO is often selected if managerial ownership is low, because it increases cash flow and value of the firm, and thus it is the method favored by outside shareholders (Niehaus 1989). Astami & Tower (2006) confirmed in their research that the level of ownership is an important factor in determining the inventory accounting policy.

Kuo (1993) listed several other potential determinants, of which the most important were following: (1) potential tax savings, (2) capital structure, (3) firm size, (4) volatility of earnings,

(5) management's compensation and (6) managers' ownership. The greater the tax savings are the greater the probability is that the company will find it easy to absorb or justify implementation costs of a new inventory valuation method (Kuo 1993). These implementation costs can be depreciated in a schedule depending on tax law. Thus if the tax savings are great, a company might easily consider changes in inventory valuation methods.

These possible tax savings have an indirect effect on stock prices of companies in public exchange. The better cash flow structure due to the benefits in tax obligations increases present values of future cash flows. Thus there is often a temptation by managers to change the policy into the direction that maximizes the stock price, and thus also their compensation if it is tied to the stock price (Hughes, Fellingham & Schwartz 1988). Related to stock prices and the benefits of tax shield, Krishnan, Srinidhi & Su (2008) investigated the effect of FIFO/LIFO choice on the cost of capital of companies. In the research it was shown that LIFO firms have lower cost of capital. This is because costs of goods sold are better matched to the current situation in LIFO. More importantly, in FIFO the costs of goods sold include goods way past and from a longer period, which brings more variation to the costs of goods sold, and thus increases volatility of earnings. Also managers face lower variability which means that it is more risky for managers to deliberately insert opportunistic discretionary accruals in LIFO to cost of goods sold account. (Krishnan et al. 2008)

When the capital structure is considered, it is generally agreed that the larger the amount of debt in a company's capital structure is, the greater the probability is that the company chooses an income-increasing method (Dhaliwal 1980). The rationale behind this hypothesis is that adoption of income-increasing accounting procedures would lower the probability of the firm getting into a technical default (Kuo 1993). By the technical default Kuo (1993) means that a company might go into bankruptcy because of accounting methods, not because of the real operations or financing. Income-increasing method might be preferable also in another sense. Namely companies have obligations to debt collectors, and when the debt is negotiated, the debtor is easier convinced that the company does not default on the payments if the income for accounting purposes is larger. All in all, when the company has a lot of debt, the method to be preferred based on previous discussion is FIFO. (Kuo 1993)

Firm size also affects the choice of inventory valuation method. Dopuch & Pincus (1988) argue that LIFO method involves high bookkeeping and tax reporting costs. Granof & Short (1984) reported that more than 30 percent of companies in their non-LIFO sample rejected LIFO because of "excessive costs" or "other adverse consequences". A survey by Hilke (1986) confirmed that these adoption costs of LIFO can be significant, in his survey adoption costs ranged from 0,7 percent to 7,9 percent of average profits. These bookkeeping and tax reporting costs are mostly fixed. Because of these fixed costs, larger companies have a comparative advantage in adopting LIFO. So it is reasonable to assume that large companies more frequently implement LIFO compared to small ones. (Kuo 1993) However, in a study by Astami & Tower (2006), which included a relatively large sample of Asian companies, size of a company was not a significant factor when inventory valuation policy was considered.

An increase in volatility of earnings increases the chance of a company reporting higher profits, which in turn increases company's political exposure (Kuo 1993). This political exposure results from the fact that companies reporting higher profits are more likely to be subjected to regulation (Watts & Zimmermann 1978). To reduce political exposure, an income-decreasing method is selected (Kuo 1993). Biddle (1980) argues that the most popular determinant for inventory accounting method is smoothing of income stream. Variability of earnings affects the choice of inventory valuation method in another way through business risk. It is reasonable that companies facing business risks use income-decreasing methods, so that if the company faces hard times in the future there is something left from the good times. (Kuo 1993)

A determinant of inventory valuation method not yet discussed is behavior of inventory in particular aspects. Cushing & LeClere (1992) found that immateriality of inventory, inventory variability and inventory obsolescence have an effect on the choice of the inventory valuation method. Immateriality of inventory is higher with FIFO companies, but the significance of this hypothesis is low. Inventory variability of FIFO companies is larger than with LIFO companies, and FIFO companies have also more obsolescence in their inventory. (Cushing & LeClere 1992) The bigger inventory variability in FIFO companies might be due to the fact that in FIFO inventory is the latest, and because of having the latest purchases it varies more. Still, it seems that the higher the risk with the inventory is, the more frequently FIFO is used.

Francis (2001) brings up one more potential determinant of inventory accounting decisions, the nature of choice. The nature of choice includes, for example, consideration whether the choice is between equally acceptable rules or not, timing decisions, lobbying activities, judgments and estimates required for the decision to be made (Francis 2001). By this Francis (2001) means that the situation where the decision is made affects the decision that managers make. For example, if alternatives are all acceptable and there is no lobbying, managers will make the decision independently and faster.

As a conclusion for choosing optimal inventory valuation method the following table is presented (Table 2-2). These factors consider mainly demographics of a company, which should affect inventory valuation policy. First, complexity of IT-systems increases the attractiveness of the weighted average cost method, because it is simpler to implement. LIFO method is challenging to implement, and thus if the IT-systems are complex, attractiveness of LIFO method decreases. If pricing is based on product costs, LIFO is more attractive because it has more accurate costing. Manipulation is possible in LIFO, but not in FIFO, so in this sense FIFO is better. The effect of restrictive covenants, such as limit for the working capital, was also covered. If there is a lot of these covenants, LIFO might be dangerous, because in LIFO a larger share of costs is allocated to costs of goods sold whereby there is less “left” to working capital accruals. High debt ratio has almost the same effect; in situations of a high debt ratio there is a possibility for technical default. Potential tax savings have a reverse effect compared to previous two; when more is allocated to costs of goods sold, tax obligations are transferred further, which has a positive present value. Firm size was said to affect the policy indirectly through implementation costs, which are mostly fixed making it more profitable to change to LIFO in big companies. Volatility of earnings increases the possibility of political exposure, and thus in that sense companies choose income-decreasing method.

Table 2-2 - Factors determining the optimal inventory valuation policy

Factor	**FIFO**	**Average Cost**	**LIFO**
Complexity of IT-systems	Neutral	+	-
Pricing is based on product costs	-	Neutral	+
Manipulation is expected	+	Neutral	-
Restrictive debt covenants	+	Neutral	-
High debt ratio	+	Neutral	-
Potential tax savings	-	Neutral	+
Firm size	-	Neutral	+
Volatility of earnings	-	Neutral	+

Next chapters cover the empirical research. In chapter 3 a framework based on this literature is formed and the research methods are discussed. Chapter 4 includes a simulation model, which is a major part of the empirical research.

3 Guidelines for Evaluating Raw Material Inventory Valuation and Product Costing

The literature review carried out previously will now be followed by an empirical study. The guidelines for this study are covered in this chapter. First, a research framework based on the literature is formed. The whole empirical study is constructed around this research framework. After that the case company of this study is introduced, because rest of the study is based on the case company environment. After case company introduction, evaluation criteria for inventory valuation methods are formed. These evaluation criteria are important because results of this research are based on them. In the final part of this chapter research methods are discussed.

3.1 Research Framework

In this empirical study the major objective is to investigate efficient inventory valuation and product costing policies in the case of raw materials (Figure 3-1). The optimal inventory valuation and product costing method depends basically on three variables: (1) how well information reflects company's performance, (2) what is the effect on tax obligations and (3) how accurate is product costing. The unique challenge in this research is the volatile raw material prices.

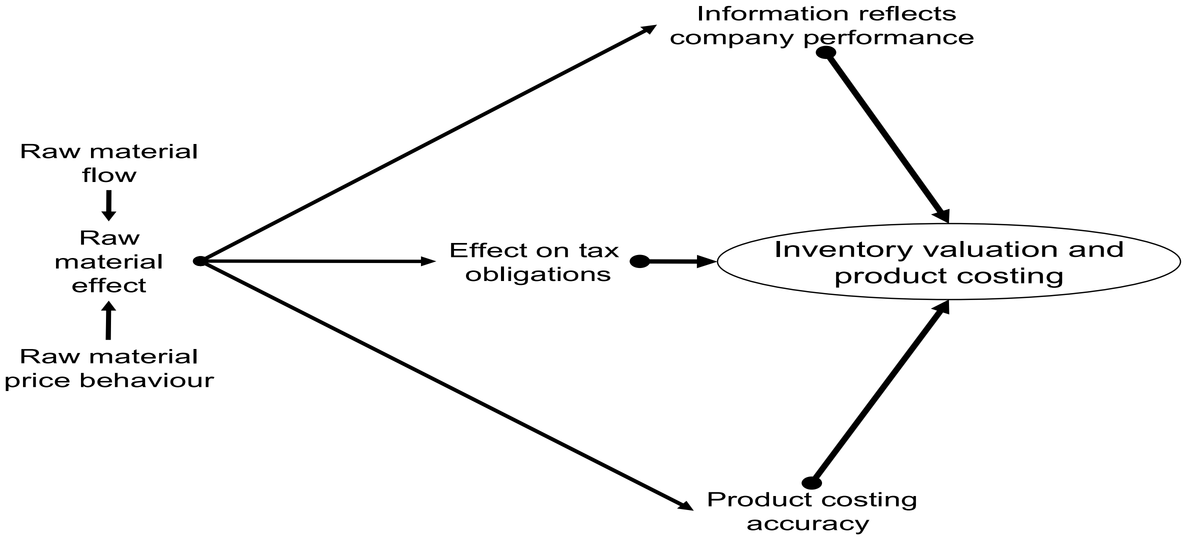

Figure 3-1 - The framework of the research

The main objective of management accounting is to give information for decision-makers. The first variable (information reflects company performance) takes this into consideration. If the inventory valuation and product costing policy give accurate information about the current situation and the recent success of the company, this information can be trusted and thus management can make reliable decisions based on the information. This information reliability affects all business levels. At product level, if the costs are allocated to the products incorrectly, it is impossible to compare profitabilities of these products. Because of these incorrectly calculated product costs, management might withdraw some profitable and leave some unprofitable products to the product line. Of course this decreases the profitability of the company.

When considering information accurateness on a business unit level, inaccurate inventory valuation gives wrong impression of business unit performance. Then some business units seem to be more profitable and some business units appear to be less profitable than they would be if the information is correct. As a result management might try to improve business units that are already very profitable, and leave some unprofitable business units uncontrolled which are really in need of serious controlling. The situation can be even worse; management might harvest profitable business units because of incorrect information.

In a company level the inaccuracy of inventory valuation will cause technical loss or profit in short-term. By technical loss or profit it is meant that by a certain method balance sheet and income statement differ when compared to another method. For example, if by a certain method inventory value is 100 000 € larger than by some other method, then the company makes a technical profit of 100 000 € by choosing the first method. This technical profit, or alternatively loss, creates problems discussed in chapter 2.4.6. One example was that management compensation is affected by this technical loss or profit, even though the performance of the company stays the same. As was mentioned earlier, the management compensation should be based on performance of the company.

Second variable in the framework is the effect on tax obligations. This variable is important because a company can achieve major alterations in cash flows by changing inventory valuation policy. These alterations are due to the fact that different methods value inventory in different ways. When by a certain method inventory value changes only a little, for example, increases by 1000 € and by a another method increase is 10 000 €, then by the latter method the increase in inventory is 9000 € more. This larger increase produces profit and of course more taxes have to be paid then.

Especially if the raw material prices are volatile, there can be huge differences in tax obligations between different inventory valuation methods. Also inflation affects considerably these differences. But what is the most important thing is that these different tax obligations have different present values. So when considering the effect of the tax obligations, present value of all tax obligations must be calculated. The method that has the smallest present value of tax obligations is the best.

Third, pricing is often based on product costs. Thus product costs need to be as accurate as possible. If the costs are not accurate, pricing is neither optimal. Because of inaccurate product costing company might sell goods that are priced too high or low, and thus lose customers or make loss. Products can include a lot of raw material, and when the price of the raw material changes, product costs should also change. If these product costs are seldom updated, they can be far from real values. Even if the company updates raw material prices continuously, the prices are still not usually optimal. This is due to the fact that the raw material costs are allocated to the product when it is transferred from raw material inventory. Yet, the product is sold to a customer after it is produced and a customer has been found. Therefore there is a time lag between the moments when the cost of raw material is allocated to the product and when the product is sold. So, it is important that allocated costs reflect the market situation when the end-product is sold.

3.2 Case Company Introduction

This subchapter first introduces the case company of this research, which is Metos Finland Oy. After that the Metos' current inventory valuation and product costing are covered.

3.2.1 Metos Finland Oy

Metos is a developer and marketer of solutions and equipment designed for professional kitchens for efficient and high quality food and beverage production. Metos is the market leader in the industry in Nordic Countries. Metos has its own sales companies in Finland, Sweden, Norway, France, Netherlands, Belgium, the Great Britain, Russia, Estonia, Lithuania and Latvia. In addition Metos has a large group of representatives in other countries. The company's factories are situated in Finland, Sweden, Estonia, Netherlands and Belgium. Metos has about 900 employees and its turnover is 160 million euros. Metos is owned by its parent company Ali Group, which is the market leader in professional kitchen industry in Europe. It has a turnover of 765 million euros and personnel of about 3900. (Metos intranet 2008)

In addition to the strong service concept Metos has a vast production. The main equipments sold include combi-kettles and dishwashing equipment and systems. Other areas of emphasis in Metos' production are ranges and bratt pans as well as equipment for food retailing, transport and catering for institutional and restaurant use. To produce such end-products a large amount of stainless steel is needed. Price of stainless steel has been very volatile for the past years, and thus product costing and inventory valuation have been recently losing reliability. (Metos intranet 2008) Because Metos is surely not the only one who is struggling with this kind of problems, the subject is really worth investigating.

3.2.2 Inventory Valuation and Product Costing at Metos Finland Oy

Metos' raw material inventory is valued by using two different methods. First, the parent company of Metos uses weighted average cost in inventory valuation, and thus Metos needs to report stainless steel inventory by using that method. Due to this, the weighted average cost method is used in ERP-systems at Metos. However, when the inventory is valued for other purposes, another method referred to here as 3-month average method, is used. In the 3-month average method inventory unit value is the average of the stainless steel prices of the three previous months. All prices are weighted equally. Inventory value is obtained by multiplying this inventory unit value by inventory units (kilograms).

What comes to product costing, there are review sessions when total product costs of a certain end-product are set for the next period. Often this period is one year. Total product costs are constant during the period. However, stainless steel as a part of the costs is not constant. The stainless steel cost is determined by the inventory valuation method of the 3-month average explained above. The stainless steel cost is unit cost based on 3-month average multiplied by the amount that the end-product uses stainless steel.

3.3 Evaluation Criteria of Inventory Valuation Methods

In this chapter evaluation criteria for the inventory valuation methods are developed. They are based on the research framework presented in the previous chapter. Following four criteria are included in the evaluation criteria: (1) *inventory value fluctuation due to stainless steel price*, (2) *product costing accurateness*, (3) *inventory value difference with weighted average cost method* and (4) *present value of tax obligations*.

The inventory value fluctuation here means the change in inventory values between successive periods. This change is due to two components: (1) change in raw material amount and (2) change in raw material prices. Raw material amounts change a lot and it is due to purchasing habits. The change due to raw material price fluctuation has nothing to do with performance of the company. So, changes in value at raw material inventory due to change in raw material price distort performance measures, and therefore it has to be minimized. So, one criterion is the *inventory value fluctuation due to stainless steel price*, which describes how much inventory fluctuates due to stainless steel price movements.

The foremost objective of product costing is to match up product costs as near to real costs as possible. This is essential if pricing is based on product costs. Costs of stainless steel are allocated to an end-product when the stainless steel goes out of raw material inventory. However, the end-product is priced and sold later. The time between the flow out of the raw material inventory and selling the end-product is commonly determined from days of supply between raw material inventory and customer. There are three main spots where the days of supply is created, and they are end-product inventory, logistics (mainly transporting) and production. Summing these days of supplies together, an average time between allocating product costs and selling end-product is obtained. From the data of the case company it can be observed that the days of supplies are on the average 1,3 months for end-product inventory and 1,2 months for logistics. Adding also work-in-progress in production, the sum of the days of supplies is around three months. So, the transfer price from raw material inventory three months before sales has to be comparable to market price at the time of sales. The criterion used here is to compare transfer price and market price three months after and it is called *product costing accurateness*.

The third evaluation criterion is based on the situation in the case company. The case company uses weighted average cost method in reporting, because the parent company and subsidiaries use that method too. The chosen inventory valuation method has to produce values near to the values obtained by weighted average cost method, otherwise there will be major differences between the reported inventory value and the inventory value used for other purposes. This difference cannot be allocated to any time period or any products and that's why it is very unwanted difference in the case company. Therefore, the difference between weighted average cost and the chosen method is the third evaluation criterion and it is called *inventory value difference with weighted average cost method*.

The final criterion is based on the fact that inventory valuation method affects tax shield as mentioned in the chapter 2.4. Tax shield gives opportunity to transfer tax obligations to later periods. If taxes can be transferred to later periods, the present value of these obligations is lower. The net present value of this benefit is considered as a final criterion and it is called *present value of tax obligations*.

3.4 Research Method of Empirical Study

The evaluation criteria imply that the research problem is quantitative, and thus quantitative research methods are used in this research to solve the research problem. In order to efficiently carry out this research, features of quantitative research methods are covered in the next section. The objective of this research is to give instructions to choose the method that is most beneficial in future. In order to evaluate future with a lot of uncertainties, simulation was chosen as the quantitative research method. Therefore simulation as a research method is introduced in section 3.4.2.

3.4.1 Quantitative Research Methods

Quantitative research is used to investigate questions related to quantities and percentages and relations between different research objects or changes in research matters. This implies that a sample needs to be big enough to represent adequately the subject being investigated. (Heikkilä 2001, 16) Therefore, in the simulation model a large number of simulations are needed. According to Nau (1995) quantitative research look for distinguishing characteristics, elemental properties and empirical boundaries and tend to measure how much or how often pertaining the research object. Thus quantitative research can be construed as a research strategy that emphasizes quantification in collection and analysis of data (Bryman & Bell 2003, 25). Quantitative research methods include, for example, a mail questionnaire and a www-questionnaire. These are surveys. Quantitative research can also be observational, where the information is gathered by making observations about the object of the research. (Heikkilä 2001, 18–19)

Quantitative research has many advantages. First, not like qualitative research methods, in quantitative research there is independence between researcher and subject being observed. Also, comparison and replication are possible in quantitative methods, and partly due to this, reliability and validity may be determined more objectively than in qualitative techniques. These comparison and replication are a special strength in this study because a number of future scenarios can be tested and compared by simulation. In quantitative methodologies the subject under analysis is measured by objective methods rather than being inferred through sensation, reflection or intuition. Also when compared to some qualitative methods, like expensive interviews, in quantitative methods the cost and effort can be a lot less. (Amaratunga, Baldry, Sarshar & Newton 2002)

Weaknesses of quantitative research include lack of ascertaining deeper underlying meanings and explanations (Amaratunga et al. 2002). This can lead to incorrect conclusions if the subject of the research is not familiar to the researcher. Often by using quantitative research methods reasonings associated with the situation are not discovered. (Heikkilä 2001, 16) However, in this research these weaknesses are not important. Literature review before this empirical study gave a deeper understanding of the subject, and by this deeper understanding reasonings behind the situation can be analyzed with the help of the simulation model.

3.4.2 Simulation as a Research Method

In this chapter the quantitative research method of this research, simulation, is covered. Simulation is imitation of an operation in a real-world process or system over time (Banks, Carson, Nelson & Nicol 2005, 3). The most significant feature of simulation is that it allows imitating one process by a more easily arranged process (Hartmann 2005).

Computer simulation is growing in popularity as a research method. There are many reasons for this popularity. First of all, many real-world problems are so complex that there is no possibility of solving these problems analytically. One advantage of simulation is that in simulation there is often no need to make assumptions about exact cause and effect of the system under study as it is in other research methods. (Dooley 2002) However, Banks et al. (2005, 3) confirm that a simulation model usually needs a set of assumptions concerning operation of the system, but less than in other methods. This makes it possible to study more complex issues. Especially in this empirical study the problem is not possible to solve analytically, because there are many complex causalities and uncertainties. If a lot of assumptions are formed, solutions of this research would not be reliable.

Whereas other studies try to explain how something happened, simulation answers to the question what if something happens. This leads to another advantage in simulation research: "moving future" makes it possible to test various kinds of scenarios for future. (Dooley 2002) Because the focus in this study is in the future, the "moving future" is essential. In simulation, for example, new hardware designs, layouts, policies and operation procedures can be tested without committing resources or disrupting ongoing process. In simulation time can be compressed, interactions of variables can be attained and bottleneck analysis can be done to increase knowledge. But the major use of simulation is that it can help to understand how the system operates. (Shannon 1992)

However, even though there are many advantages in using simulation, few disadvantages also exist. First of all, model building requires special skills. Simulation results are also difficult to interpret. Especially differentiating results of system interaction and randomness might be challenging. Simulation modeling and analysis can be time-consuming and increase costs heavily. Simulation is also often used even though it is not reasonable and there are analytical solutions. (Banks et al. 2005, 6) Because of these disadvantages, there was a versatile preparation done for the simulations. First, researcher familiarized himself all-around with simulation as a research method and the problem at hand. By this preparation the skills to build the simulation model were acquired. In order to obtain more accurate results, the number of replications was high. To interpret the results easily, an unambiguous evaluation criteria based on literature was developed (see section 3.3).

Before using simulation as a tool, it needs to be analyzed whether simulation as a method is appropriate. Banks & Gibson (1997) formed the following ten rules for determining when simulation is not appropriate. Simulation should not be used when the problem can be solved by common sense or analytically, or on the other hand, when the problem is too complex to be simulated. Simulation is not reasonable when real-world experiment is more easily or less costly done, or if costs exceed savings due to simulation. Another method than simulation should be used if there are not enough resources or data available for simulation, or not enough time to use the results from simulation. Simulation is not appropriate if simulation model can't be verified or validated, or simulation project expectations cannot be met. (Banks & Gibson 1997) In preparation for the simulation it was observed that none of these features exists in the simulation model.

Although there are many factors eliminating the use of simulation, there are still many situations when simulation is useful. Many authors have discussed this, and the following list of eleven possible purposes of simulation is a summary by Banks et al. (2005, 4). Especially items 1, 4, 6 and 11 were exploited in this research.

1. Simulation enables experimentation with internal interactions of a complex system.
2. Informational, organizational and environmental changes can be simulated, and the effect of these can be observed.
3. Knowledge that evolves when designing simulation model can be used for improving system under investigation.
4. Changing simulation inputs and observing outputs can produce valuable insight for determining interactions of variables.
5. Simulation can be used as a pedagogical device to reinforce analytical solution methodologies.
6. Simulation can be used to test new designs or policies before implementation.
7. Simulation can be used to verify analytical solutions.
8. Simulating different capabilities of a machine can help to determine requirements for it.
9. Simulation models designed to educational purposes can ease learning process with less cost and disruption.
10. Simulation can be used to visualize behavior of a system.

11. Modern systems can be so complex that its internal interactions are sometimes discovered only through simulation. (Banks et al. 2005, 4)

Based on the previous discussion simulation was chosen as the research method for the empirical part of this study. In the next chapter the simulation model is introduced and in chapter 5 results of the simulation are presented.

4 Simulation Model to Evaluate Inventory Valuation Methods

This chapter introduces the simulation model developed for evaluating different inventory valuation methods. By this simulation model inventory valuation and product costing can be tested under volatile raw material prices. The purpose of this empirical research is to investigate possible stainless steel inventory valuation methods.

Simulation model of this research can characterized as an input-output-model. In this chapter the inputs and the model are covered. The outputs of the model are presented in chapter 5. In section 4.1 data used for modeling the inputs is introduced. In section 4.2 the main input is modeled, which is the stainless steel price. In modeling stainless steel prices it was observed that the prices depend largely on nickel prices, and therefore in section 4.3 nickel prices are modeled. Thereafter rest of the inputs, purchase and production behavior, are modeled in section 4.4. The simulation model itself is introduced in section 4.5.

4.1 Data Used in Simulation Model

In building the simulation model various data was used. The quantitative data used included material flow of stainless steel, stainless steel prices and data acquired from public sources. The material flow data was acquired from the case company. Purchases were obtained from a financial management software called eOffice. This purchase data was in euros, but it was easily converted to kilograms with the help of stainless steel price data. Production data was gathered from the production department. It was already in kilograms. Stainless steel prices depend on customer and the prices that Metos pays were obtained from the purchasing department.

The data acquired from public sources included data for the regression model in chapter 4.2. This data includes nickel price, chrome price, global nickel inventory and $/€-ratio data. Nickel price data was obtained from Metalsmarket (2008). Chrome and global nickel inventory data was obtained from Metalprices (2008) and $/€-ratio data was acquired from Oanda (2008). This public source data is available all-around world.

4.2 Modeling Stainless Steel Prices

The main variable in the simulation model is the price of stainless steel. However, there is no exchange market for stainless steel and also it needs other raw material for its production, so it can be assumed that the price depends on some other specific variables. So, variables determining the stainless steel price are investigated. The tool used here is regression analysis.

The confidence level in regression analysis is 95 %. Variables that are not significant on that level are dropped from simulation model. The 95 % confidence level is quite normal, because most often used confidence levels are 90, 95 and 99 % (Nist/Sematech 2006). In order to avoid spurious regression, the variables in the regression analysis are one-month relative changes. The one-month relative change is defined as follows:

$$(4.1)\quad \gamma_s(\boldsymbol{variable\ i})_t = \frac{\boldsymbol{variable\ i}_t - \boldsymbol{variable\ i}_{t-1}}{\boldsymbol{variable\ i}_{t-1}}$$

where γ_s means one-month relative change and t is time in months. From now on in this subchapter the data are these monthly relative changes.

Stainless steel includes two major components, which are chrome and nickel. So, it is reasonable to expect that the prices of those components have an effect on the price of stainless steel. Other variables tested were $/€-ratio and nickel inventory. The former was tested because there is trade in both currencies. The nickel inventory was necessary because nickel is the main raw material in stainless steel, and the inventories reflect the availability of nickel.

For all of these variables time lags of 0, 1, 2, 3, 4 and 5 months are considered, making in total 24 variables (4 variables x 6 lags). Therefore, first a correlation analysis was made in order to decrease the number of variables. In the correlation analysis the variables that are not significant on 95 % confidence level are removed before the regression analysis. In the following table (Table 4-1) there is the correlation analysis. From the table it can be observed that six variables have significant correlation with stainless steel price change. These are nickel price change with lags 1, 2 and 3 months and global nickel inventory change with lags 0, 1 and 2 months. Slightly surprising is that chrome price does not affect stainless steel price, even though it is an important component of stainless steel.

Table 4-1 - Correlation analysis: testing significance of correlations between independent variables and stainless steel price

	Stainless steel price change		
	Correlation	*p-value*	
€/$-ratio change (lag 0)	-0.07	0.69	
€/$-ratio change (lag 1)	0.06	0.73	
€/$-ratio change (lag 2)	0.18	0.31	
€/$-ratio change (lag 3)	-0.02	0.92	
€/$-ratio change (lag 4)	0.05	0.76	
€/$-ratio change (lag 5)	0.25	0.15	
Nickel price change (lag 0)	0.18	0.29	
Nickel price change (lag 1)	0.53	<0,01	*
Nickel price change (lag 2)	0.67	<0,01	*
Nickel price change (lag 3)	0.38	0.03	*
Nickel price change (lag 4)	0.16	0.37	
Nickel price change (lag 5)	0.13	0.46	
Chrome price change (lag 0)	0.10	0.55	
Chrome price change (lag 1)	0.07	0.69	
Chrome price change (lag 2)	0.15	0.40	
Chrome price change (lag 3)	-0.14	0.42	
Chrome price change (lag 4)	-0.33	0.05	
Chrome price change (lag 5)	-0.17	0.32	
Global nickel inventory change (lag 0)	-0.47	<0,01	*
Global nickel inventory change (lag 1)	-0.51	<0,01	*
Global nickel inventory change (lag 2)	-0.62	<0,01	*
Global nickel inventory change (lag 3)	-0.30	0.08	
Global nickel inventory change (lag 4)	-0.30	0.08	
Global nickel inventory change (lag 5)	-0.16	0.35	

* = significant on 95 % confidence level

Nickel inventories affect nickel availability, and therefore there might be correlation between inventories and price. If correlated variables are left into regression analysis, there would be multicollinearity. Therefore correlations between variables need to be removed. There are two main ways to remove multicollinearity, and they are (1) creating new variables based on correlated variables and (2) removing variables having least correlation with the dependent variable. (Dougherty 2002, 134, 136) In order to keep the simulation model uncomplicated, the second method is used here.

The correlation considered to be multicollinearity is situation-dependent. Here multicollinearity is defined to be present if the absolute value of correlation is over 0,35. In the following table (Table 4-2) there are correlations between the significant independent variables (nickel inventories and prices), and between the dependent variable (stainless steel price) and the significant independent variables. After having multicollinearity removed, only three independent variables are present. These are nickel price changes with lags 1, 2 and 3 months.

Table 4-2 - Correlation analysis: removing multicollinearity

	γ[*SS(t)*]	γ[*N(t-1)*]	γ[*N(t-2)*]	γ[*N(t-3)*]	γ[*NI(t)*]	γ[*NI(t-1)*]	γ[*NI(t-2)*]
γ[*SS(t)*]	1.00						
γ[*N(t-1)*]	0.53	1.00					
γ[*N(t-2)*]	0.67	0.26	1.00				
γ[*N(t-3)*]	0.38	-0.03	0.25	1.00			
γ[*NI(t)*]	-0.47	-0.45*	-0.41*	-0.07	1.00		
γ[*NI(t-1)*]	-0.51	-0.36*	-0.46*	-0.43*	-0.40*	1.00	
γ[*NI(t-2)*]	-0.62	-0.34	-0.36*	-0.47*	-0.36*	-0.39*	1.00

γ[*SS(t)*] = stainless steel price change at time t
γ[*N(t-i)*] = nickel price change at time t-i
γ[*NI(t-i)*] = global nickel inventory change at time t-i
* = absolute correlation over 0,35

To be sure of that the right variables are present in the final regression model, regression models including €/$-ratio change, chrome price change, nickel price change and nickel inventory change individually as independent variables and stainless steel price change as the dependent variable were constructed. As is evident based on the correlation analysis presented earlier (Table 4-1), none of the €/$-ratio changes or chrome price changes were significant in regressions. The only significant nickel inventory change was nickel inventory change with lag 2. However, in a regression model where this nickel inventory change and significant nickel price changes (lag 1, 2 and 3) were independent variables and stainless steel price change the dependent variable, the nickel inventory change was not significant anymore. Therefore, the significant variables based on regression analysis are also the nickel price changes with lags 1, 2 and 3.

Next regression analysis, where nickel price changes are independent variables, is executed. Stainless steel price change is the dependent variable. The regression analysis is in the following table (Table 4-3). Intercept is not significant on 95 % confidence level, and therefore it is not included in the regression analysis presented in the table. All the nickel price changes regressed are clearly significant, and the whole regression model is significant because F-probability is less than 0,001. Parameters estimated are positive, which means that the positive change in nickel prices implies positive change in stainless steel price, and vice versa. The R-squared value is 0,66, implicating that 66 % of total variation in stainless steel prices can be explained by nickel price changes.

Table 4-3 - Regression analysis: Nickel price changes with lags 1, 2 and 3 months are independent variables, stainless steel price change is dependent variable

Variable	Variable coefficient	Variable t-statistics	t-statistic p-value	Standard error
Nickel price change (lag 1)	0.258	3.701	<0.001	0.071
Nickel price change (lag 2)	0.323	4.454	<0.001	0.074
Nickel price change (lag 3)	0.165	2.352	0.025	0.072

Observations	35
Multiple R	0.813
R-square	0.660
Adjusted R-square	0.608
Standard Error	0.048
df/Regression	3
df/residual	32
df/total	35
F-value	20.749
F-probability	<0,001

Based on the previous information regression model for the simulations is as follows:

$$(4.2)\quad \gamma_s[\boldsymbol{SS}(\boldsymbol{t})]=0.26\gamma_s[\boldsymbol{N}(\boldsymbol{t}-1)]+0.32\gamma_s[\boldsymbol{N}(\boldsymbol{t}-2)]+0.16\gamma_s[\boldsymbol{N}(\boldsymbol{t}-3)]+\varepsilon_t$$

where $\gamma_s[\boldsymbol{SS}(\boldsymbol{t})]$ is the relative stainless steel price change between time t and time t-1, $\gamma_s[\boldsymbol{N}(\boldsymbol{t}-\boldsymbol{i})]$ is the relative nickel price change between time t-i and time t-i-1, *t* is time in months and ε_t is the error term at time t.

In the simulations estimated parameters of the regression model are let to vary. The distribution followed is normal distribution where the mean is variable coefficient and standard deviation is standard error from previous table (Table 4-3). In order to simulate nickel prices, they are modeled in the next subchapter.

4.3 Modeling Nickel Prices

In section 2.2.1 the time-series modeling was presented in theory. Now these theoretical models are used in practice to model nickel price behavior. The data on which the modeling is based is obtained from the website of Metalsmarket (Metalsmarket 2008). The index used here is “Nickel cash official fixing -ask” -index. Nickel price indices compared to each other have only slight relative differences, so for the purpose of this study this index can be well used. In the following figure (Figure 4-1) is the index from February 2000 to June 2008. From the figure it is observed that volatility has had dramatic increase after 2006.

Figure 4-1 - “Nickel cash official fixing - ask” -index behavior from 4th of February 2000

For modeling purposes the price index is converted into logarithmic. This is because in the forecasting models it is possible that prices can change negative if logarithms are not used. Converting prices logarithmic is done by taking logarithm as follows:

(4.3) $\boldsymbol{npl}(\boldsymbol{t}) = \ln(\boldsymbol{np}(\boldsymbol{t}))$

where $\boldsymbol{npl}(\boldsymbol{t})$ is the logarithmic nickel price at time t, $np(t)$ is the nickel price at time t and t is the time in months. In simulations this logarithmic price is simulated. After these logarithmic prices have been created in the simulations, they are converted back to normal price as follows:

(4.4) $\boldsymbol{np}(\boldsymbol{t}) = \boldsymbol{e}^{\boldsymbol{npl}(\boldsymbol{t})}$

where again $\boldsymbol{npl}(\boldsymbol{t})$ is the logarithmic price, $np(t)$ is the price and t is time in months.

The main forecasting models in chapter 2.2.1 included autoregressive (AR), moving-average (MA) and autoregressive moving-average (ARMA) processes. In the following it is tested how well these models fit into logarithmic nickel price data and what kind of model should be chosen for further analysis. In testing the models nickel price is modeled using different numbers of lags for forecast error (moving-average process) and previous values (autoregressive process).

The first task is to investigate which of the ARMA-models is the best. Brooks (2002, 257) introduces three common information criteria for determining the best ARMA-model. These are Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC) and Hannan-Quinn information criterion (HQIC). Algebraically these are expressed as follows:

$$\text{(4.5)} \quad \boldsymbol{AIC} = \ln(\bar{\sigma}^2) + \frac{2\boldsymbol{m}}{\boldsymbol{T}}$$

$$\text{(4.6)} \quad \boldsymbol{SBIC} = \ln(\bar{\sigma}^2) + \frac{\boldsymbol{m}}{\boldsymbol{T}}\ln \boldsymbol{T}$$

$$\text{(4.7)} \quad \boldsymbol{HQIC} = \ln(\bar{\sigma}^2) + \frac{2\boldsymbol{m}}{\boldsymbol{T}}\ln(\ln \boldsymbol{T})$$

where $\bar{\sigma}^2$ is the residual variance, $\boldsymbol{m}$ is the total number of estimated parameters and $\boldsymbol{T}$ is the sample size. (Brooks 2002, 257)

According to Brooks (2002, 257) none of these three criteria outperforms others. So in the following all these three criterions are taken into account. In this analysis the ARMA-models tested included seven different combinations of autoregressive lags (in months): (a) 1, (b) 1-2, (c) 1-3, (d) 1-4, (e) 1-5, (f) 1-6 and (g) 1-6 and 12. Lags 1 to 6 were tested because it was assumed that nickel prices might be most correlated with past values. Lag 12 in model (g) was tested because it was assumed that there might be some seasonal behavior in nickel prices. It was also assumed that if a lag i is included in the best model, then all lags smaller than i would be included also, except for lag 12. For example, model including lags 1 and 3, but not 2, was not tested. Lags of moving-average (in months) were determined to be (a) 0, (b) 1, (c) 1-2 and (d) 1-3. Testing more lags seems illogical, because future values of nickel price hardly correlate with error value obtained much earlier. In the following table (Table 4-4) is presented Akaike's information criterion (AIC) with different ARMA-models. As is observed, the best model is ARMA(2,1), because it has the minimum AIC (notice negative numbers) (marked in yellow in the table). Second best is AR(1)-model (marked in green).

Table 4-4 - AIC with different ARMA-models

AIC	***MA-lags***			
AR-lags	*0*	*1*	*1-2*	*1-3*
1	-156.3	-154.9	-153.2	-155.1
1-2	-154.9	-158.1	-156.1	-153.2
1-3	-152.9	-154.6	-154.6	-153.1
1-4	-155.0	-153.4	-152.8	-153.8
1-5	-153.3	-151.4	-152.8	-150.3
1-6	-151.7	-153.0	-150.1	-148.3
1-6 and 12	-151.5	-149.5	-145.2	-134.4

In the next table (Table 4-5) Schwartz Bayesian Information Criterion (SBIC) with different ARMA-models is presented. The best is AR(1)-model, because it has minimum SBIC. Now the second best is ARMA(2,1).

Table 4-5 - SBIC with different ARMA-models

SBIC	***MA-lags***			
AR-lags	*0*	*1*	*1-2*	*1-3*
1	-151.1	-147.1	-142.8	-142.0
1-2	-147.1	-147.7	-143.1	-137.5
1-3	-142.5	-141.6	-138.9	-134.9
1-4	-142.0	-137.8	-134.6	-133.0
1-5	-137.7	-133.2	-132.0	-126.9
1-6	-133.4	-132.1	-126.7	-122.3
1-6 and 12	-130.6	-126.1	-119.2	-105.7

In the following table (Table 4-6) Hannan-Quinn information criterion (HQIC) is presented. As is observed, AR(1)-model is the best in this criterion. So because AR(1)-model is the best in two criterions (SBIC and HQIC) and the second best in one criterion (AIC) it is selected for further analysis.

Table 4-6 - HQIC with different ARMA-models

HQIC	***MA-lags***			
AR-lags	*0*	*1*	*1-2*	*1-3*
1	-154,2	-151,8	-149,0	-149,8
1-2	-151,7	-153,9	-150,8	-146,8
1-3	-148,7	-149,3	-148,2	-145,7
1-4	-149,8	-147,1	-145,4	-145,4
1-5	-147,0	-144,1	-144,4	-140,9
1-6	-144,3	-144,5	-140,6	-137,8
1-6 & 12	-143,1	-140,0	-134,7	-122,8

Based on the previous, AR(1) is the best model, and thus for further analysis this AR(1)-model is chosen. The model expressed in equation form is:

$$(4.8)\quad \boldsymbol{npl}(\boldsymbol{t}) = 0.00643 + 0.993\boldsymbol{npl}(\boldsymbol{t}-1)$$

where $\boldsymbol{npl}(\boldsymbol{t})$ is the logarithmic nickel price at time t and *t* is time in months.

In estimating volatility ARCH- and GARCH-models can be used. These were introduced in chapter 2.2.1. However, here only ARCH-models are tested. This is because it can be assumed that current nickel price volatility has no correlation with volatility occurring much earlier, which would be needed in order to make GARCH better than ARCH. ARCH-models tested here included lags of (a) 0, (b) 1, (c) 1-2, (d) 1-3, (e) 1-4, (f) 1-5, (g) 1-6 and (h) 1-6 and 12. So, it is assumed that the volatility reflects on error terms at maximum 6 months before. Also seasonality was tested and thus lag of 12 months was used.

ARCH-model models current volatility based on lagged squared error terms. So it is basically the same as autoregressive model, but now the power of two of error terms are modeled. This is observed from the next equation:

$$(4.9)\quad \sigma_{\boldsymbol{t}}^2 = \eta_0 + \eta_1\boldsymbol{u}_{\boldsymbol{t}-1}^2 + \eta_2\boldsymbol{u}_{\boldsymbol{t}-2}^2 + \ldots + \eta_{\boldsymbol{q}}\boldsymbol{u}_{\boldsymbol{t}-\boldsymbol{q}}^2$$

where u_t is the error term, η_i is the coefficient of squared error term , σ_t^2 is the variance and *t* is time in months. Therefore, the same criteria as in ARMA-modeling can be used to model ARCH-models. So, AIC, SBIC and HQIC are calculated and these are in the following table (Table 4-7). As is observed, the best ARCH-model based on these information criteria is ARCH(0)-model, which means constant variance. ARCH(0)-model has a variance σ^2 of 0,0117, which implies standard deviation σ of 0,108.

Table 4-7 - AIC, SBIC and HQIC with different ARCH-models

	Order of ARCH 0	1	1-2	1-3	1-4	1-5	1-6	1-6 & 12
AIC	-517,9	-516,1	-514,5	-512,9	-511,9	-510,6	-509,0	-507,9
SBIC	-515,3	-510,9	-506,7	-502,4	-498,8	-495,0	-490,8	-487,1
HQIC	-516,9	-514,0	-511,3	-508,6	-506,6	-504,3	-501,6	-499,5

As a summary of the previous, the logarithmic nickel prices were modeled. The model type used was the AR(1)-model with constant variance. The logarithmic prices for the simulation model are modeled as follows:

$$(4.10)\quad \boldsymbol{npl}(\boldsymbol{t}) = 0.00643 + 0.993\boldsymbol{npl}(\boldsymbol{t}-1) + \varepsilon_{\boldsymbol{np}}$$

where $\boldsymbol{npl}(\boldsymbol{t})$ is the logarithmic nickel price at time t, *t* is the time in months and ε_{np} is the error term. ε_{np} follows normal distribution N(0, $0{,}108^2$).

4.4 Simulation of Material Flow

Other variables not yet covered are (1) purchases into raw material inventory and (2) raw material flow into production, which is the flow out of the raw material inventory. The case company does not order raw material periodically or the same amounts every time because their business is volatile and partly seasonal. Purchases are done by estimating future usage based on past and future plans. In purchases volatility is increased because stainless steel deliveries are not exact, in fact delivery times are months with a major variation. On the other hand, production is also not constant. It is mainly affected by demand and production performance.

Amounts of purchases and production are expected to be related with each other. Correlations between these can be observed from the next table (Table 4-8). In the table there is a correlation matrix in which variables are production and purchases with lags 0, 1, 2 and 3 months. p-values are given in parentheses. The only significant correlation at 95 % confidence level is the correlation between purchases at time t and purchases at time t-1 (t is in months), their correlation being -0,54 (marked in yellow in the table). This means that if there are a lot of purchases in current month, then it is expected that the purchases in the next month are lower than on the average. Surprisingly, there is no significant correlation between purchases and production. The most significant correlation between purchases and production is between purchases at time t and production at time t-3 with correlation 0.38, because it has the smallest p-value of 0.18 (marked in green).

Table 4-8 - Correlation analysis: correlations between purchases and production

	pu (lag 0)	*pu (lag 1)*	*pu (lag 2)*	*pu (lag 3)*	*pr (lag 0)*	*pr (lag 1)*	*pr (lag 2)*	*pr (lag 3)*
pu (lag 0)	1.00 (0.00)							
pu (lag 1)	-0.54 (0.03)*	1.00 (0.00)						
pu (lag 2)	0.24 (0.39)	-0.54 (0.03)*	1.00 (0.00)					
pu (lag 3)	-0.08 (0.77)	0.24 (0.39)	-0.54 (0.03)*	1.00 (0.00)				
pr (lag 0)	0.22 (0.40)	-0.26 (0.33)	0.05 (0.85)	-0.21 (0.47)	1.00 (0.00)			
pr (lag 1)	0.16 (0.55)	0.22 (0.40)	-0.26 (0.33)	0.05 (0.85)	0.04 (0.87)	1.00 (0.00)		
pr (lag 2)	-0.29 (0.29)	0.16 (0.55)	0.22 (0.40)	-0.26 (0.33)	0.11 (0.70)	0.04 (0.87)	1.00 (0.00)	
pr (lag 3)	0.38 (0.18)	-0.29 (0.29)	0.16 (0.55)	0.22 (0.40)	-0.31 (0.28)	0.11 (0.70)	0.04 (0.87)	1.00 (0.00)

pu = purchases
pr = production
* = significant on 95 % confidence level

The correlations between purchases at time t and at time t-1 and between purchases at time t and production at time t-3 are included into simulation model. Simulating correlated inputs can be done by Cholesky's decomposition method (Haas 1999). Here the simulation of purchases and production for the next five years is done in five main steps:

1. Set t=0 and simulate purchases at time t
2. Calculate Z' based on simulated purchases at time t (Z' defined later in this chapter)
3. Simulate purchases at time t+1
4. If t≥3, then simulate production at time t-3 based on Z' in step 2, otherwise go to step 5
5. If t=63, then finish simulation, otherwise go back to step 2 and change t to t+1.

In the first phase purchases at t=0 are simulated as follows:

$$pu_0 = \psi_{pu} + Z_0 \sigma_{pu}$$

where pu_0 is the purchases at time 0, ψ_{pu} is the average of purchases, σ_{pu} is the standard deviation of purchases and Z_0 is randomly generated from N(0,1).

In the second step Z' value of purchases at time t is calculated as follows:

$$(4.11)\quad Z'_t = \frac{pu_t - \psi_{pu}}{\sigma_{pu}}$$

where pu_t is the purchases at time t (t is in months), ψ_{pu} is the average of purchases and σ_{pu} is the standard deviation of purchases. Because purchases are set to follow normal distribution, Z'_t follows N(0,1).

In the third step purchases at time t+1 are simulated by Cholesky's method:

$$(4.12)\quad pu_{t+1} = \rho_{t,t+1}\sigma_{pu}Z'_t + \sigma_{pu}\sqrt{1-\rho^2_{t,t+1}}Z_{t+1} + \psi_{pu}$$

where pu_{t+1} is the purchases at time t+1 (t is in months), ψ_{pu} is the average of purchases, σ_{pu} is the standard deviation of purchases, Z'$_t$ is the Z' based on purchases at time t (see equation (4.11)), Z_{t+1} is a random number from N(0,1) and $\rho_{t,t+1}$ is the correlation between purchases at time t and at time t+1.

In the fourth step production at time t-3 is simulated based on Z'_t as follows:

$$(4.13)\quad pr_{t-3} = \rho_{pr_{t-3},pu_t}\sigma_{pr}Z'_t + \sigma_{pr}\sqrt{1-\rho^2_{pr_{t-3},pu_t}}Z_{pr} + \psi_{pr}$$

where ρ_{pr_{t-3},pu_t} is the correlation between purchases at time t and production at time t-3 (t is in months), σ_{pr} is the standard deviation of production, Z'$_t$ is the Z' based on purchases at time t, Z_{pr} is randomly generated from N(0,1) and ψ_{pr} is the average of production (obviously same as for purchases).

In the fifth step simulation is ended if t=63 (5 years and 3 months), because then purchases and production for the next five years have been simulated. If time is less than 63 months, then the simulation for the next month is done by going back to step 2 and increasing time by one month.

However, it is not obvious that simulating autocorrelated series of lag 1 by Cholesky's decomposition is appropriate. If it is appropriate, then correlation and variance should remain constant with respect to time. Correlation between purchases at time t and at time t+1, when

Cholesky's method is used, is calculated as follows. Calculation rules used in deriving are in the footnotes:

(4.14) $$\rho_{t,t+1}^{Cholesky} = \frac{Cov(pu_t, pu_{t+1})}{\sigma_{pu}\sigma_{pu}} = \frac{Cov(\sigma_{pu}Z'_t + \psi_{pu}, \rho_{t,t+1}\sigma_{pu}Z'_t + \sigma_{pu}\sqrt{1-\rho_{t,t+1}^2}Z_{t+1} + \psi_{pu})}{\sigma_{pu}\sigma_{pu}}$$

$$= \frac{Cov(\sigma_{pu}Z'_t, \rho_{t,t+1}\sigma_{pu}Z'_t + \sigma_{pu}\sqrt{1-\rho_{t,t+1}^2}Z_{t+1} + \psi_{pu}) + Cov(\psi_{pu}, \rho_{t,t+1}\sigma_{pu}Z'_t + \sigma_{pu}\sqrt{1-\rho_{t,t+1}^2}Z_{t+1} + \psi_{pu})}{\sigma_{pu}\sigma_{pu}}$$ [1]

$$= \frac{Cov(\sigma_{pu}Z'_t, \rho_{t,t+1}\sigma_{pu}Z'_t + \sigma_{pu}\sqrt{1-\rho_{t,t+1}^2}Z_{t+1} + \psi_{pu})}{\sigma_{pu}\sigma_{pu}}$$ [2]

$$= \frac{Cov(\sigma_{pu}Z'_t, \rho_{t,t+1}\sigma_{pu}Z'_t) + Cov(\sigma_{pu}Z'_t, \sigma_{pu}\sqrt{1-\rho_{t,t+1}^2}Z_{t+1}) + Cov(\sigma_{pu}Z'_t, \psi_{pu})}{\sigma_{pu}\sigma_{pu}}$$ [3]

$$= \frac{Cov(\sigma_{pu}Z'_t, \rho_{t,t+1}\sigma_{pu}Z'_t)}{\sigma_{pu}\sigma_{pu}}$$ [4]

$$= \frac{\rho_{t,t+1}\sigma_{pu}^2 Var(Z'_t)}{\sigma_{pu}\sigma_{pu}} = \rho_{t,t+1}$$ [5]

where pu_{t+1} and pu_t are the purchases at time t+1 and at time t (t is in months), ψ_{pu} is the average of purchases, Z'_t is the Z' based on purchases at time t, Z_{t+1} is randomly generated from N(0,1) and σ_{pu} is the standard deviation of purchases. It is observed that from correlation based on Cholesky's method the assumed correlation can be derived. It is the same as correlation in Cholesky's method. Therefore, correlation remains constant with respect to time, because time t in the equation can be replaced by any time. On the other hand, variance of purchases in Cholesky's method is calculated as follows:

---

[1] Cov(X,Y+Z) = Cov(X,Y) + Cov (X,Z)

[2] Cov(ψ_{pu},X) = 0

[3] Cov(V,X+Y+Z) = Cov(V,X) + Cov(V,Y) + Cov(V,Z)

[4] Cov(ψ_{pu},X) = 0
Cov(Z'_t, Z_{t+1}) = 0

[5] Cov(aX,Y) = aCov(X,Y)
Cov(Z'_t, Z'_t) = Var(Z'_t) = 1, because Z'_t follows N(0,1)

$$(4.15)\quad Var(pu_{t+1})^{Cholesky} = Var\left(\rho_{t,t+1}\sigma_{pu}Z'_t + \sigma_{pu}\sqrt{1-\rho^2_{t,t+1}}Z_{t+1} + \psi_{pu}\right)$$

$$= Var(\rho_{t,t+1}\sigma_{pu}Z'_t) + Var(\sigma_{pu}\sqrt{1-\rho^2_{t,t+1}}Z_{t+1}) + 2Cov(\rho_{t,t+1}\sigma_{pu}Z'_t, \sigma_{pu}\sqrt{1-\rho^2_{t,t+1}}Z_{t+1}) \quad {}^{6}$$

$$= \rho^2_{t,t+1}\sigma^2_{pu}Var(Z'_t) + \sigma^2_{pu}(1-\rho^2_{t,t+1})Var(Z_{t+1}) \quad {}^{7}$$

$$= \rho^2_{t,t+1}\sigma^2_{pu} + \sigma^2_{pu} - \rho^2_{t,t+1}\sigma^2_{pu} = \sigma^2_{pu} \quad {}^{8}$$

As is observed, variance in Cholesky's method is equal to assumed variance. Therefore, Cholesky's method can be used to simulate autocorrelated series.

For the simulation of material flow, averages and standard deviations of production and purchases are needed. Monthly standard deviation of purchases is 50,3 % and of production 32,3 % from the mean values in the case company's data. Starting inventory for the simulation model is set to be four month's average production of stainless steel. This was because the days of supply at the raw material inventory have been on the average four months.

Now all of the variables needed for the simulation model have been modeled. The next subchapter concentrates on presenting the simulation model in which the variables play a major role.

4.5 Structure of Simulation Model

In this chapter the structure of the simulation model is described. In the following figure (Figure 4-2) a single simulation process with a single inventory valuation method is presented. The model starts by simulating nickel prices (based on section 4.3). Based on nickel prices stainless steel prices are simulated (section 4.2). At the same time production and purchases of stainless steel are also simulated (section 4.4). After these inputs have been determined, production and purchases in euros based on the selected inventory valuation method are calculated. The final phase in the modeling is inventory valuation. The final inventory is calculated by deducting the production and adding the purchases to the initial inventory. This is done for 20 periods, and

---

[6] Var(X+ψ_{pu}) = Var(X)

Var(X+Y) = Var(X) + Var(Y) + 2Cov(X,Y)

[7] Var(aX) = a^2Var(X)

Cov(Z'$_t$, Z$_{t+1}$) = 0

[8] Var(Z'$_t$) = Var(Z$_{t+1}$) = 1

because one period is three months long, the model simulates 5 years of future (20 x 3 months). Next all these steps are discussed in more detail and by giving examples.

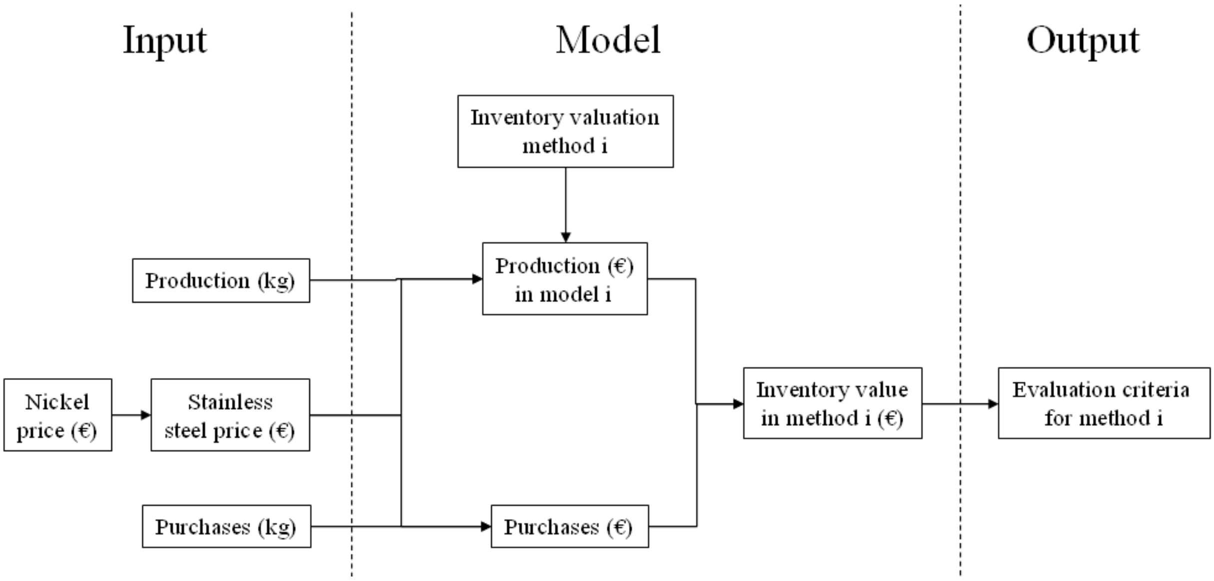

Figure 4-2 - A single simulation process with one inventory valuation method

First to be considered is nickel price. In the following figure (Figure 4-3) there are 20 examples of nickel price paths in the simulations. In total there were 5000 simulations and thus 5000 different paths. Prices are normal prices, not logarithmic. As the model suggests, there are no cycles or trends.

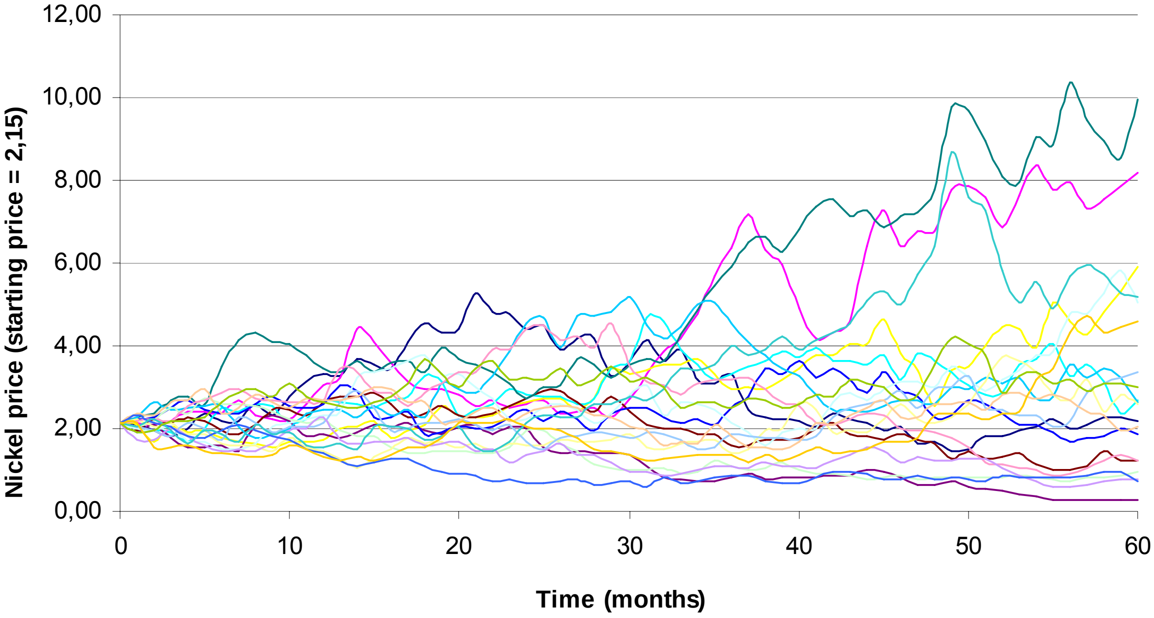

Figure 4-3 - 20 random nickel price paths in simulations

Stainless steel prices are obtained from these nickel price paths. In the following figure (Figure 4-4) there are examples of price paths, which were formed in the same simulations as nickel price paths in the previous figure. As is observed, the trend of those paths seems to follow nickel price paths, as it should. The same colored paths in these figures are results of the same replication.

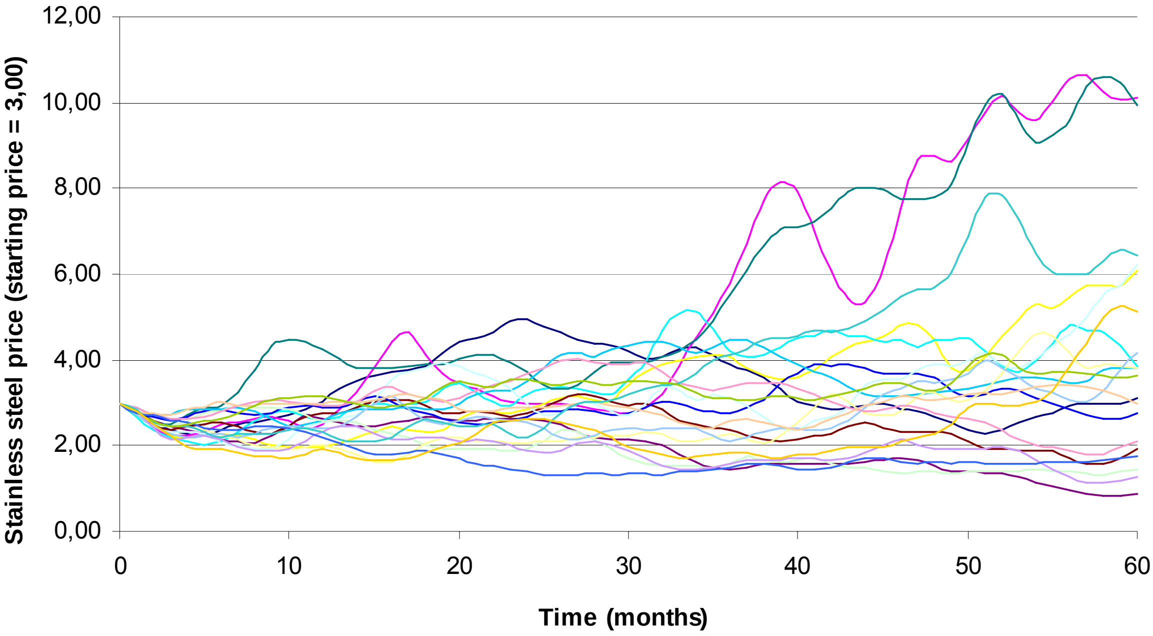

Figure 4-4 - 20 random stainless steel price paths in simulations

In order to form inventory values by different inventory valuation methods, purchases and production in kilograms have to be simulated. Purchases and production in the next five years were simulated 5000 times, and in the following figure (Figure 4-5) there is an example of a simulated path of purchases, production and inventory in kilograms.

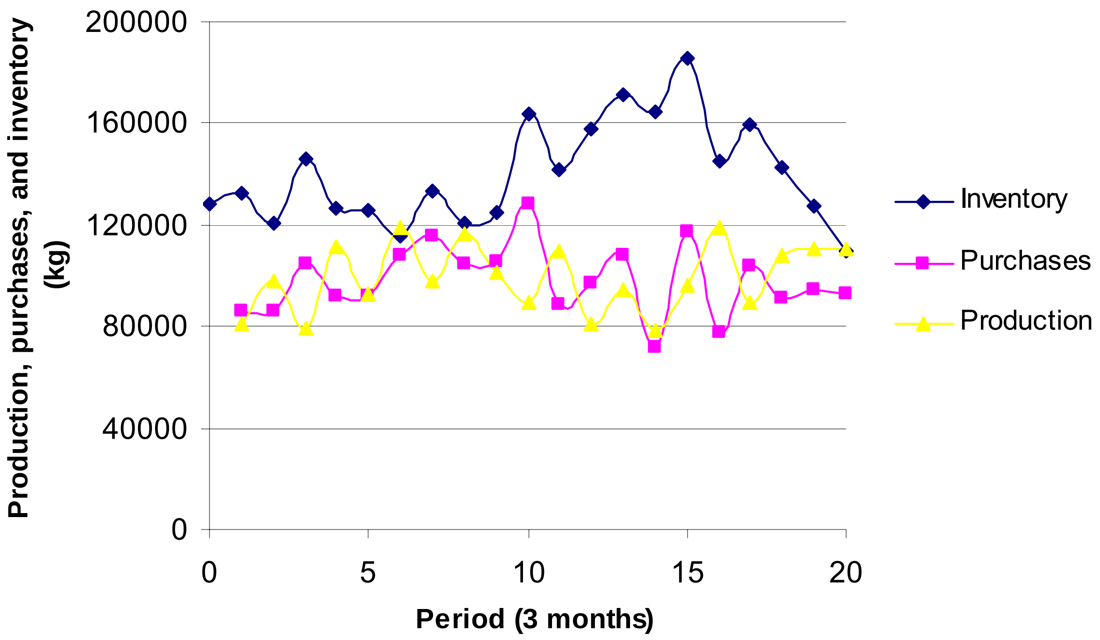

Figure 4-5 - Amount of production, purchases and inventory in one random path

Material flow has to be translated into "money flow" with different methods. This is done by calculating inventory values with different methods taking stainless steel prices into account. In the following figure (Figure 4-6) there are inventory values by different methods from the same path as described in the previous figure (Figure 4-5). In the simulation model five inventory valuation methods were evaluated, which were (1) weighted average cost, (2) first-in first-out (FIFO), (3) last-in first-out (LIFO), (4) market price and (5) 3-month average method. 3-month average was chosen to be evaluated because it is the current method at the case company, and the four other methods were chosen based on literature.

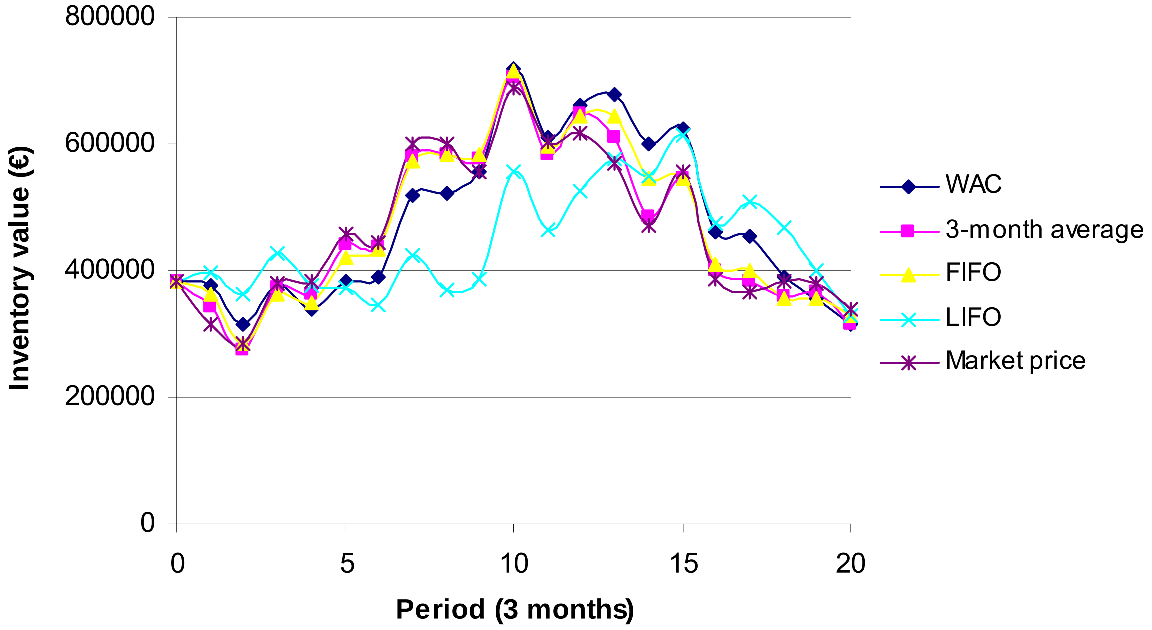

Figure 4-6 - Inventory value by different methods in one random path

Based on these inventory values the different inventory valuation methods are evaluated by evaluation criteria introduced in chapter 3.3.

5 Results of Simulations

In this section outputs of the simulation model are discussed, which are the results based on the evaluation criteria. In chapter 5.1 inventory value fluctuation due to volatility of stainless steel prices, which was the first evaluation criterion, is discussed (see evaluation criteria in chapter 3.3). After that the second criterion, product costing accurateness, is dealt. Then the third criterion, which is the difference with weighted average cost method, is covered in section 5.3. In section 5.4 the present value of tax shield is discussed. After that combined results of the simulations and conclusions based on simulation results are covered in sections 5.5 and 5.6. In section 5.7 a scenario analysis in order to recognize causes of the results and sensitivity analysis in order to fit these results into various circumstances is performed.

5.1 Inventory Value Fluctuation Due to Stainless Steel Prices

The inventory value fluctuation that is due to volatility of stainless steel prices is bad for management accounting because then the measures of management accounting are not reliable. Therefore, this fluctuation has to be minimized. Inventory value fluctuation due to volatility of stainless steel prices is minimized when the difference between successive inventory unit values is minimized and inventory is low. Therefore, the measure for the inventory value fluctuation due to volatility of stainless steel prices (*IVF*) is as follows:

$$IVF(t) = \left|(Iuv(t) - Iuv(t-1)) \cdot Inv(t)\right| \tag{5.1}$$

where $Iuv(t)$ is the inventory unit value at time t, $Inv(t)$ is the inventory in kilograms at time t and t is time in 3-month periods.

In simulations *IVF* is the per period average (3 months) of five years of future. So, one value represents an average of 20 periods (5 years, 4 periods per year). The following figure (Figure 5-1) shows the probability distribution of *IVF* in simulations. As is observed, with LIFO *IVF* is with a probability of over 80 % under 15 000 euros. Therefore, in most cases LIFO has low inventory value fluctuation due to stainless steel prices, which makes inventory values more reliable. This makes damaging side effects due to the fluctuation weak.

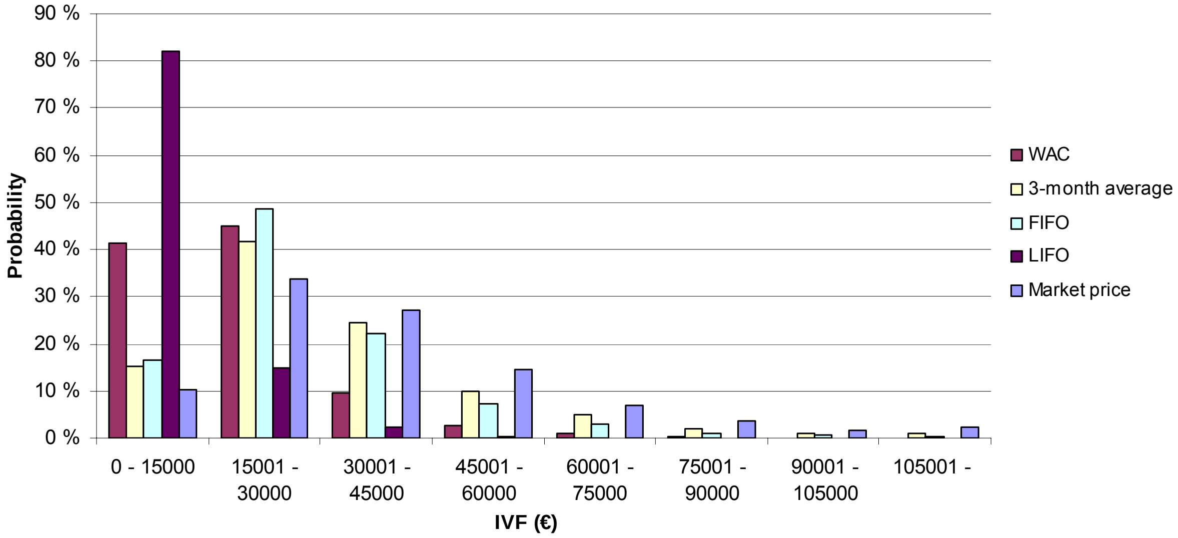

Figure 5-1 - The distributions of IVF in the simulations (n=5000) with different methods

In the following table (Table 5-1) the key figures of *IVF* in the simulations are presented. If the methods are ranked based on lowest average, which probably is the best way to rank, then market price method is clearly not suitable in this sense, because its average exceeds 38 000 €. Almost as bad a situation is with 3-month average. LIFO is clearly the best with *IVF* on the average 68 % lower than the current method of the case company (3-month average).

Table 5-1 - The average, standard deviation, standard error, minimum and maximum of IVF in simulations (n=5000) with different methods

	WAC	**3-month average**	**FIFO**	**LIFO**	**Market price**
Average	19541	32193	28508	10448	38508
Standard deviation	12198	20500	17079	7775	24840
Standard error	173	290	242	110	351
Minimum	1573	2441	2470	0	3152
Maximum	190551	269844	242962	98789	363362

Even though the numbers of *IVF* are important, it is essential to compare *IVF* with inventory value to see how large fraction of inventory value *IVF* is. The compared inventory value is inventory value of WAC. The same inventory value is used for all the methods, because then the effect on income statement can be better compared. As mentioned in chapter 2.1.3, the main effect of inventory value fluctuation is on income statement and its reliability. For example, in LIFO inventory value is usually smaller than in others, and if *IVF* in LIFO is compared to LIFO inventory, then LIFO would seem to have worse effect on income statement than justifiable. Therefore, the Relative *IVF* (*RVIF*) is as follows:

$$(5.2) \quad RIVF(t) = \frac{IVF(t)}{Iva_{WAC}(t)} = \frac{\left|(Iuv(t) - Iuv(t-1)) \cdot Inv(t)\right|}{Iva_{WAC}(t)}$$

where $Iuv(t)$ is the inventory unit value at time t, $Inv(t)$ is the inventory in kilograms at time t, $Iva_{WAC}(t)$ is the inventory value with weighted average cost method at time t and t is time in 3-month periods. In the next figure (Figure 5-2) simulated distributions of *RIVF* can be seen. As is observed, LIFO has *RVIF* less than 4 % with a probability of nearly 80 %, which means that the fluctuation in LIFO method has only little effect on income statement, even though if inventory is large.

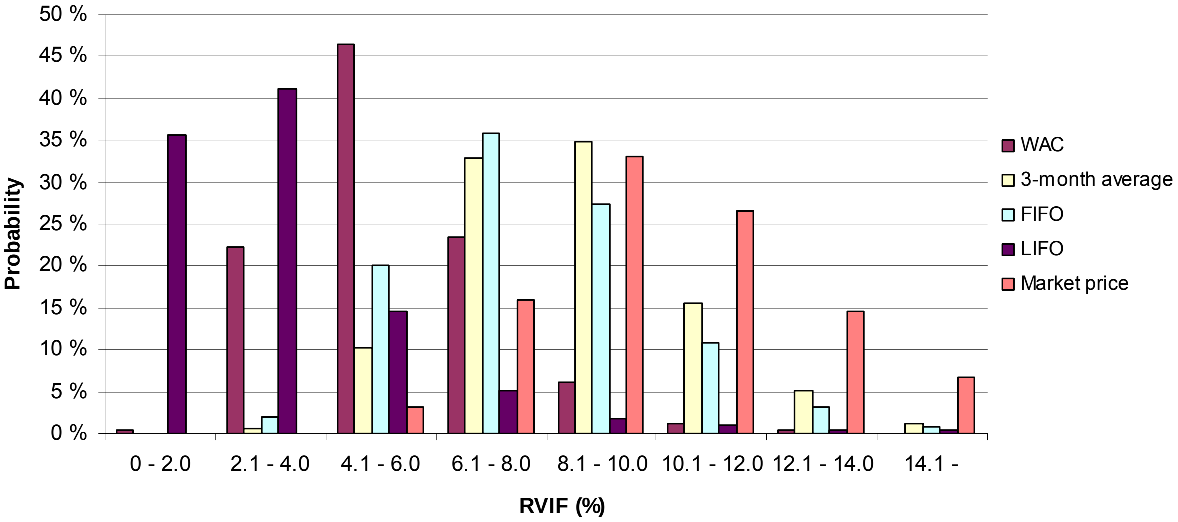

Figure 5-2 - The distributions of RIVF in the simulations (n=5000) with different methods

In the next table (Table 5-2) the key figures of *RVIF* in simulations are presented. It is observed that with the LIFO method average of *RVIF* is only 3.1 % and in the market price method over 10 %. Therefore, there are significant differences between different inventory valuation methods in this criterion. An important thing to notice in these results is that the standard error is very small in this measure (also in other methods, see results in chapters 5.2, 5.3 and 5.4). This is because the number of replications in simulations were set to be as high as 5000. Therefore, the main conclusions based on these results are reliable.

Table 5-2 - The average, standard deviation, standard error, minimum and maximum of RIVF in simulations (n=5000) with different methods

	WAC	**3-month average**	**FIFO**	**LIFO**	**Market price**
Average	5.4 %	8.5 %	7.8 %	3.1 %	10.1 %
Standard deviation	1.8 %	2.1 %	2.2 %	2.2 %	2.5 %
Standard error	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Minimum	1.3 %	2.6 %	2.2 %	0.0 %	3.4 %
Maximum	17.5 %	20.5 %	20.3 %	22.5 %	24.2 %

Low *RIVF* (or *IVF*) with the LIFO results from the fact that in the LIFO method the costs of goods sold include the latest purchases, and thus the inventory left can include purchases much earlier. Therefore, in LIFO method there is a part of inventory that doesn't change at all from time to time, and then neither does its value. Market price and 3-month average methods relate to the latest stainless steel prices, and because of heavy fluctuations in stainless steel prices, the inventory values with these methods fluctuate very much.

5.2 Product costing accurateness

Changes in stainless steel prices should affect product costing and thus pricing. When costs are set to a product these costs should reflect the market situation at the time when the end-product is priced and sold. If the product costs differ greatly from the market value, the costs of product are either too low or too high. That causes problems of either selling goods for too low price and making loss or trying to sell for too high price and losing sales. Thus the difference between costs of stainless steel and market price of stainless steel at the time of selling the end-product should be minimized. Time between allocating stainless steel product costs to an end-product and selling the end-product is on the average 3 months (see section 3.3). If inventory is high, the problem is enhanced. Based on the previous, product costing accurateness (*PCA*) is calculated as follows:

(5.3) $\boldsymbol{PCA(t)} = \left| \left(\boldsymbol{cu(t)} - \boldsymbol{mp(t+1)} \right) \cdot \boldsymbol{Inv(t)} \right|$

where $Inv(t)$ is the inventory in kilograms at time t, *cu(t)* is the cost of stainless steel unit at time t, *mp(t+1)* is the market price of stainless steel at time t+1 and t is the time in 3-month periods.

In simulations *PCA* is per period average (3 months) over the five-year interval of future. So, again one value represents the average of 20 periods (5 years, 4 periods per year). In the following figure (Figure 5-3) are the probability distributions of *PCA* in the simulations. As is observed, *PCA* is less than 30 000 euros in market price method with a probability of over 90 % and in LIFO with a probability of over 80 %. In FIFO the situation is much worse. Therefore, in market price and LIFO product costs are quite reliable, and if pricing is essential and based on costs, these methods are worth further investigation.

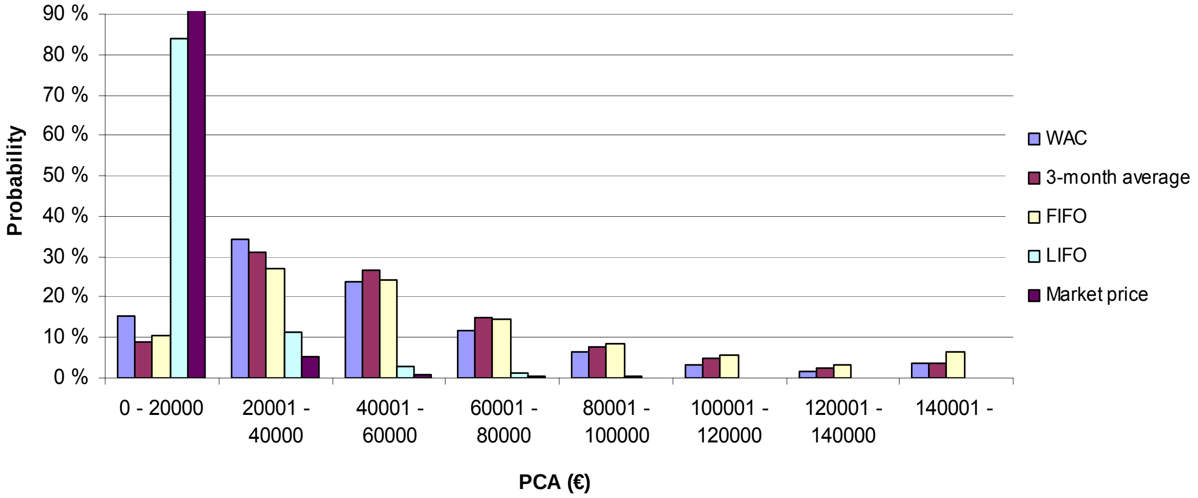

Figure 5-3 - The distributions of PCA in simulations (n=5000) with different methods

In the following table (Table 5-3) the key figures of *PCA* in simulations are presented. Because FIFO has the highest average, it can be considered the worst. It has *PCA* of 62 756 € on the average, which is about nine times more than that of the market price method. Market price and LIFO are clearly better than the others.

Table 5-3 - The average, standard deviation, standard error, minimum and maximum of PCA in simulations (n=5000) with different methods

	WAC	**3-month average**	**FIFO**	**LIFO**	**Market price**
Average	50244	56187	62756	12176	6974
Standard deviation	40360	38898	50965	16021	9754
Standard error	571	550	721	227	138
Minimum	3475	4463	3738	2	1
Maximum	807916	621965	935432	381534	262198

Again it is important to calculate *PCA* and compare it with inventory value. Now the inventory value compared with is the value of each method itself. This is because now the main effect is on product costing, which affects pricing. In pricing the percentage error of product costs (calculated with inventory value of method itself) is important, and the absolute error compared to some specific inventory value has no significance. Whether product costs are 10 or 1000, by this percentage the error reliability of these costs can be evaluated. Therefore, Relative *PCA* (*RPCA*) is obtained by dividing *PCA* with inventory value at time t:

$$(5.4)\quad RPCA(t) = \frac{PCA(t)}{Iva(t)} = \frac{\left|\left(cu(t) - mp(t+1)\right) \cdot Inv(t)\right|}{Iva(t)}$$

where *Iva(t)* is the inventory value at time t, $Inv(t)$ is the inventory in kilograms at time t, *cu(t)* is the cost of stainless steel unit at time t, *mp(t+1)* is the market price of stainless steel at time t+1 and t is time in 3-month periods. In the next figure (Figure 5-4) are distributions of *RPCA* with different methods. With market price method *RPCA* is less than 3 % with a probability of over 80 %, and thus product costing based on market price method has a high reliability.

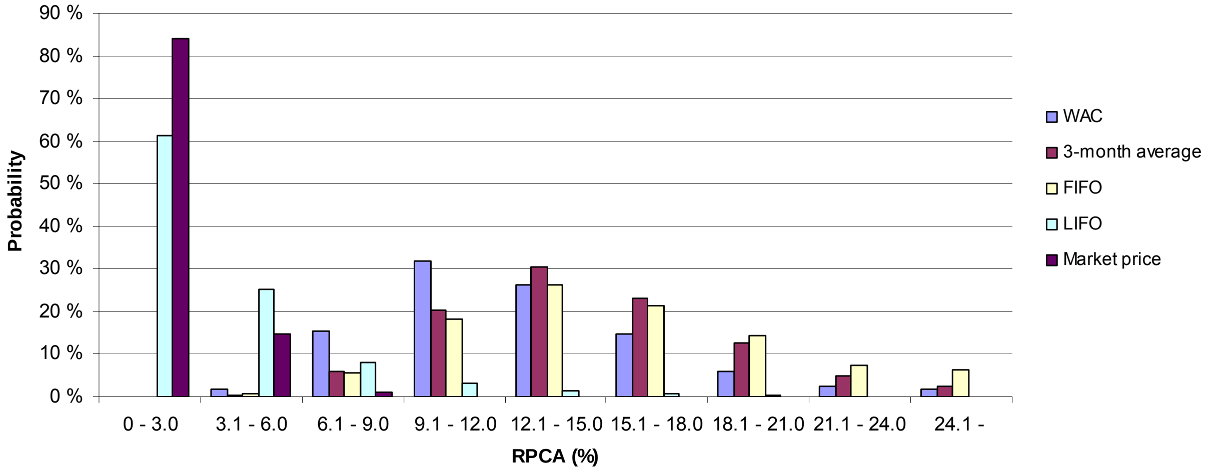

Figure 5-4 - The distributions of RPCA in simulations (n=5000) with different methods

In the following table (Table 5-4) the key figures of *RPCA* in simulations are presented. The best methods are clearly market price and LIFO, because their average is significantly smaller than that of the others. In the market price method standard deviation is also small, which means that there is some, but very small, error existing in product costing. Therefore, product costing using market price method is less risky in this sense.

Table 5-4 -The average, standard deviation, standard error, minimum and maximum of RPCA in simulations (n=5000) with different methods

	WAC	**3-month average**	**FIFO**	**LIFO**	**Market price**
Average	12.7 %	14.7 %	15.7 %	3.2 %	1.7 %
Standard deviation	4.2 %	4.2 %	5.1 %	3.2 %	1.4 %
Standard error	0.1 %	0.1 %	0.1 %	0.0 %	0.0 %
Minimum	3.1 %	4.2 %	3.2 %	0.0 %	0.0 %
Maximum	53.9 %	47.2 %	53.5 %	46.5 %	12.9 %

The lower value of LIFO compared to WAC and FIFO is due to the fact that in LIFO the latest purchased raw material is allocated to the product costs. The latest purchase prices are often nearest to the current market prices, because the time between purchase of raw material and selling the end-product containing that raw material is shortest. Market price is very efficient because the only thing causing error in it is the 3-month lag between allocating costs of raw material and selling the end-product.

5.3 Eliminating Contradiction with Reported Inventory Value

Parent company of Metos, which is AliGroup, uses the weighted average cost for inventory valuation (Ali Group 2007). Consequently, reporting at Metos has to be made with this method, and thus the company's ERP-system has to calculate the inventory value also by the weighted average cost method. When inventory is valued for other purposes by a method different than the weighted average cost, there will be a difference between the value reported and the value for other purposes. This causes problems in reporting, which are case company specific and beyond the scope of this research. However, the difference between the chosen inventory valuation method and weighted average cost method (*DWAC*) has to be minimized. Therefore the figure to be minimized is as follows:

(5.5) $DWAC(t) = \left| Iva(t) - Iva_{WAC}(t) \right|$

where $Iva(t)$ is the inventory value at time t, $Iva_{WAC}(t)$ is the inventory value with the weighted average cost method at time t and *t* is time in 3-month periods.

In simulations *DWAC* is per-period average over a five-year interval of future. In the following figure (Figure 5-5) there are probability distributions of average *DWAC* in the simulations. As is observed from the figure, in the FIFO method *DWAC* is less than 30 000 € with a probability of over 80 %. This means that with the FIFO method contradiction between WAC and FIFO is the least, eliminating major part of the problems associated with this conflict. Of course, WAC has no difference with itself and it is the best in this criterion.

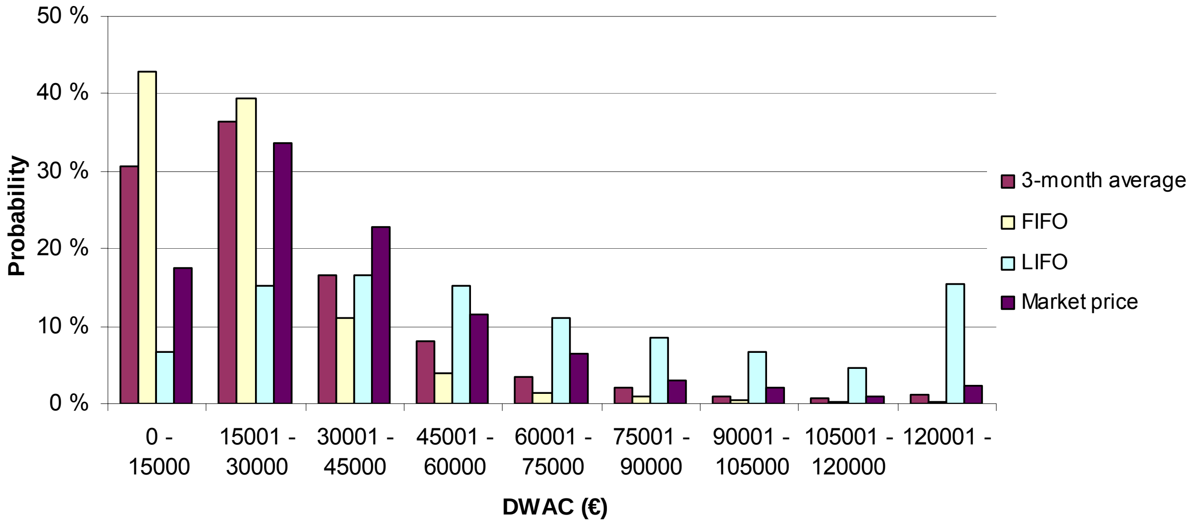

Figure 5-5 - The distributions of DWAC in simulations (n=5000) with different methods

In the next table (Table 5-5) the key figures of average *DWAC* in simulations are presented. The weighted average cost method is not included in the table and in the previous figure, because *DWAC* with weighted average cost is 0. As is observed from the table, FIFO is the best method (after WAC) because it has the lowest average of 20 757 €. The worst is clearly LIFO, which yields value over three times as high.

Table 5-5 - The average, standard deviation, standard error, minimum and maximum of DWAC on a five-year interval in simulations (n=5000) with different methods

	3-month average	**FIFO**	**LIFO**	**Market price**
Average	28542	20757	74078	37242
Standard deviation	25112	16221	65635	30711
Standard error	355	229	928	434
Minimum	1379	1170	1304	2320
Maximum	407573	255341	688817	547283

Relative *DWAC* (*RDWAC*) is probably more informative than *DWAC*. It tells how big the difference is compared to inventory value. The compared inventory value is now inventory value of WAC, because the reported inventory value is calculated by that method. Thus *RDWAC* is calculated as follows:

$$(5.6)\quad RDWAC(t) = \frac{DWAC(t)}{Iva_{WAC}(t)} = \frac{|Iva(t) - Iva_{WAC}(t)|}{Iva_{WAC}(t)}$$

where $\boldsymbol{Iva(t)}$ is the inventory value at time t, $Iva_{WAC}(t)$ is the inventory value with weighted average cost method at time t and *t* is time in 3-month periods. In the next figure (Figure 5-6) there are the probability distributions of average *RDWAC* on a five-year interval of future. As is observed, all the methods (except WAC) almost always have value above 3 %, and therefore WAC is the only method by which the inventory value can be brought close to the reported inventory value.

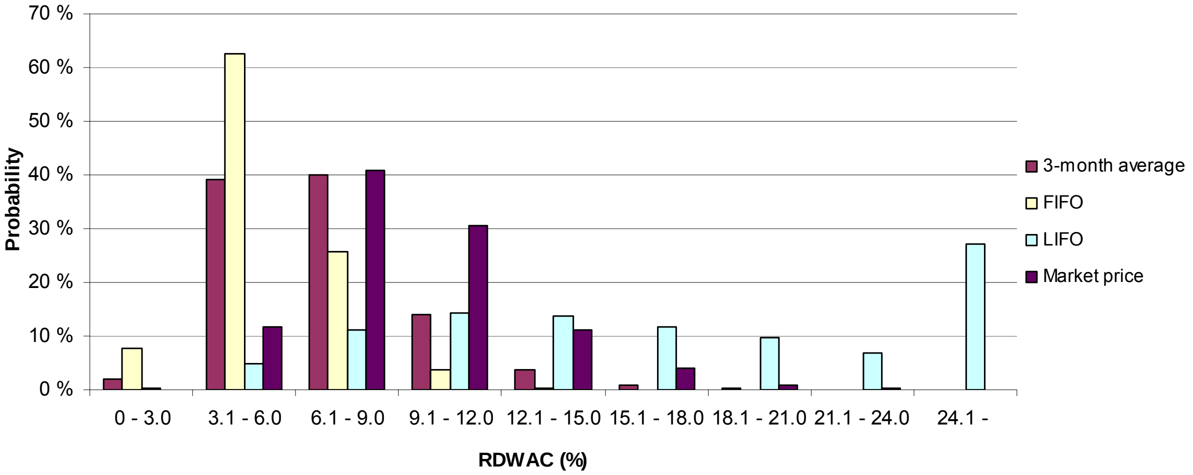

Figure 5-6 - The distributions of RDWAC in simulations (n=5000) with different methods

In the next table (Table 5-6) there are key figures of *RDWAC* in simulation. As is observed, LIFO has an average of nearly 20 %, while the other methods have averages lower than 10 %. So, because of a high average LIFO is clearly the poorest in this criterion.

Table 5-6 - The average, standard deviation, standard error, minimum and maximum of RDWAC in simulations (n=5000) with different methods

	3-month average	FIFO	LIFO	Market price
Average	7.0 %	5.3 %	19.8 %	9.3 %
Standard deviation	2.7 %	1.8 %	13.2 %	3.2 %
Standard error	0.0 %	0.0 %	0.2 %	0.0 %
Minimum	1.7 %	1.0 %	2.1 %	2.2 %
Maximum	27.2 %	17.0 %	126.0 %	36.5 %

This large *RDWAC* of LIFO is quite obvious, because in LIFO method the inventory items can reach far away from present, but the inventory in WAC can be quite new, especially if the company operates on low inventories.

5.4 Profit from Tax Shield

According to literature, if there is inflation, and thus increase in raw material prices (or deflation and decrease in raw material prices), different inventory valuation methods form different amounts of tax shields. Furthermore, if company is producing profit, tax shield can be used to transfer the tax obligations to later periods. This option is worth money, because present value of tax obligations in later periods is smaller than if the obligation is due in the current period. So, the benefit due to tax shield needs to be evaluated.

Amount of tax shield depends on change in inventory value. If the change is negative, ensuing loss in inventory produces tax shield, and if the change is positive, tax shield is negative. Tax shield due to inventory value change (*TS*) is then calculated as follows:

$$(5.7)\quad TS(t) = Iva(t-1) - Iva(t)$$

where *Iva(t)* is the inventory value at time t and *t* is time in 3-month periods. However, in order to convert tax shield into value, the change in tax obligations due to tax shield needs to be calculated. To do the calculation, tax rate is used. Tax rate in Finland is 26 %, and because the case company pays taxes to Finland, this rate is used. The value of tax shield (*VTS*) is as follows:

$$(5.8)\quad VTS(t) = TS(t) \cdot Tax\,rate = \left(Iva(t-1) - Iva(t)\right) \cdot 26\%$$

However, this value of tax shield needs to be converted into present value of tax shield (*PV(TS(t))*). This is done by discounting it as follows:

(5.9) $$\boldsymbol{PV}(\boldsymbol{TS}(\boldsymbol{t})) = \frac{\boldsymbol{VTS}(\boldsymbol{t})}{(1+\boldsymbol{r})^{\boldsymbol{t}}} = \frac{(\boldsymbol{Iva}(\boldsymbol{t}-1) - \boldsymbol{Iva}(\boldsymbol{t}))\cdot 26\%}{(1+\boldsymbol{r})^{\boldsymbol{t}}}$$

where *r* is the discount rate for a 3-month period. The discount rate is set to be 4,7 % (20 % annually) for further calculations. To calculate the total present value of the tax shield over the 5-year interval (20 periods) in simulations, sum of the present values is calculated, and it is defined as *PV(TTS)*:

(5.10) $$\boldsymbol{PV}(\boldsymbol{TTS}) = \sum_{\boldsymbol{t}=1}^{20} \boldsymbol{PV}(\boldsymbol{TS}(\boldsymbol{t})) = \sum_{\boldsymbol{t}=1}^{20} \frac{(\boldsymbol{Iva}(\boldsymbol{t}-1) - \boldsymbol{Iva}(\boldsymbol{t}))\cdot 26\%}{(1+\boldsymbol{r})^{\boldsymbol{t}}}$$

It is of no use to calculate tax shields of individual inventory valuation methods. Instead *PV(TTS)* is compared to the *PV(TTS)* of the 3-month average method. By this measure the change in the present value of tax shield can be evaluated, if the current inventory valuation method at the case company is changed. The difference here is called tax shield profit (*TSP*), and it is calculated as follows:

(5.11) $$\boldsymbol{TSP} = \boldsymbol{PV}(\boldsymbol{TTS}) - \boldsymbol{PV}(\boldsymbol{TTS})_{3\boldsymbol{ma}}$$

where *PV(TTS)* relates to total present value of tax shield and $\boldsymbol{PV}(\boldsymbol{TTS})_{3\boldsymbol{ma}}$ is total present value of tax shield with 3-month average method.

In the following figure (Figure 5-7) there are distributions of *TSP* with different methods. It can be observed that with the LIFO method the variation of *TSP* is high, and thus changing current inventory valuation method to LIFO is more risky than changing to other methods.

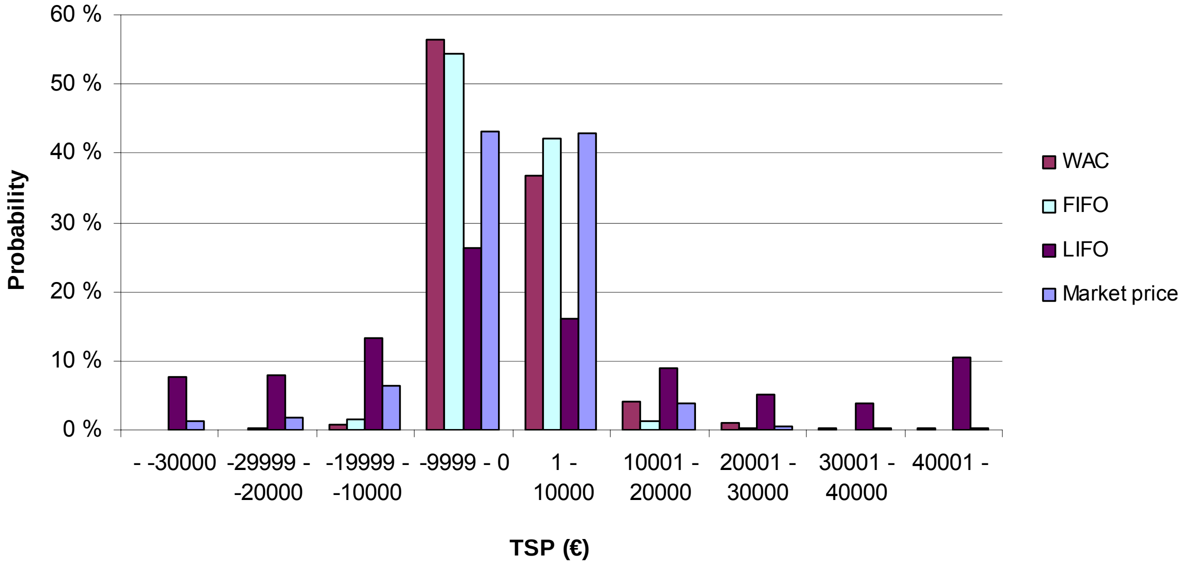

Figure 5-7 - The distributions of TSP in simulations (n=5000) with different methods

In the following table (Table 5-7) there are key figures of *TSP* in simulations. As is observed, the average of *TSP* with the market price method is the worst. LIFO method has the largest tax shield profit which is on the average 4880 €.

Table 5-7 - The average, standard deviation, standard error, minimum and maximum of TSP in simulations (n=5000) with different methods

	WAC	**3-month average**	**FIFO**	**LIFO**	**Market price**
Average	769	0	-305	4880	-1075
Standard deviation	6796	0	4456	34821	9257
Standard error	96	0	63	492	131
Minimum	-53411	0	-46863	-98531	-155345
Maximum	154255	0	84931	517441	101483

If it is assumed that *TSP* remains the same in five-year periods after the first one, then *TSP* to infinity (*TSPI*) can be calculated as follows:

$$(5.12)\quad TSPI = TSP + \frac{TSP}{(1+R)^5} + \frac{TSP}{(1+R)^{10}} + \frac{TSP}{(1+R)^{15}} \ldots$$

where *R* is the annual discount rate. This reminds of the dividend discount model, which states the following:

(5.13) $$V_0 = \frac{D_1}{k-g}$$

where V_0 is the value of dividends at time 0, D_1 is the dividends one year after time 0, k is the rate of return used for discounting and g is the yearly growth of dividends (Gordon 1959). However, in this case one period is five years and it is assumed that there is no growth. So, *TSPI* is as follows:

(5.14) $$TSPI = TSP + \frac{TSP}{(1+R)^5 - 1}$$

In the following table (Table 5-8) *TSPI* is given for each inventory valuation method except for the 3-month average method which has *TSP* and *TSPI* of 0. As is observed, the highest *TSPI* is in LIFO which is nearly 8 200 €. This means that if the 3-month average method is changed to LIFO, alterations in tax obligations will be worth nearly 8 200 € in present value.

Table 5-8 - Average TSP and TSPI in simulations (n=5000)

	TSP	*TSPI*
WAC	769	1286
FIFO	-305	-510
LIFO	4880	8158
Market price	-1077	-1800

However, if the change of the inventory valuation system is not as risky as annual 20 % discount rate would imply, a different discount rate should be used. In the following figure (Figure 5-8) *TSPI* with different methods with discount rates of 10 %, 15 %, 20 % and 25 % are presented. As is observed, *TSPI* approaches zero as discount rate increases. So, the higher the discount rate, the less significance *TSPI* has in choosing inventory valuation method.

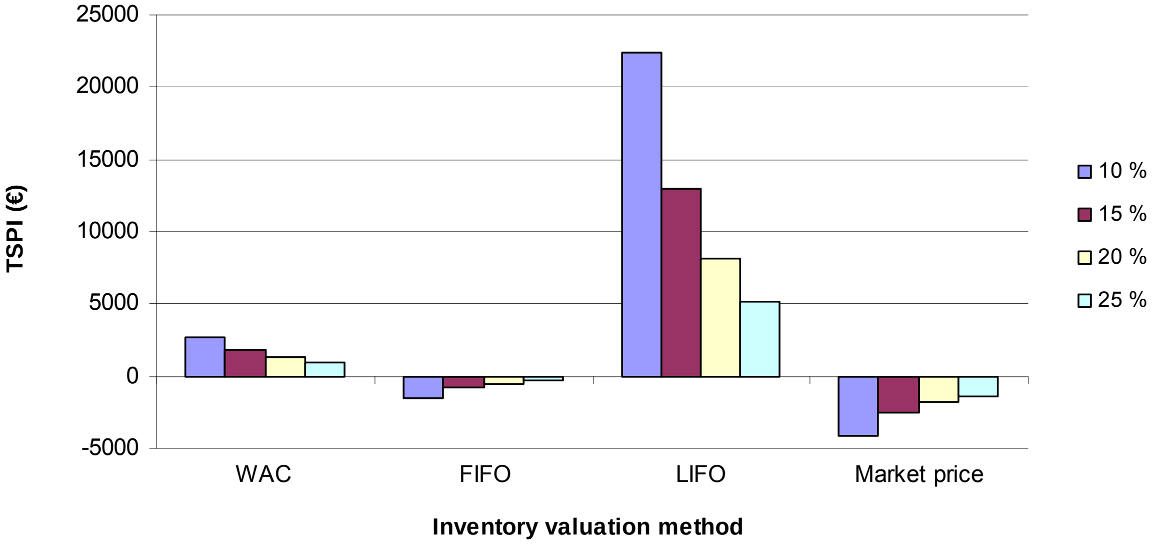

Figure 5-8 - Averages of TSPI with different rates of return with different inventory valuation methods

In the next table (Table 5-9) there are the averages presented in the previous figure. As is observed, changing the current method of 3-month average to LIFO has a high effect on present value of tax shield, but changing to any other method than LIFO has a relatively low effect on the present value of tax obligations.

Table 5-9 - Average TSPI with different discount rates with different methods

	Discount rate			
	10 %	*15 %*	*20 %*	*25 %*
WAC	2649	1780	1286	945
FIFO	-1491	-821	-510	-342
LIFO	22401	12974	8158	5197
Market price	-4090	-2561	-1800	-1346

Now all the evaluation criteria have been covered. Next all these measures are evaluated together in section 5.5.

5.5 Best Inventory Valuation Methods Based on Simulations

In the next table (Table 5-10) there is a summary of the previous results. Rankings in different categories are also included in the table, and they are the numbers on the right side of every value. Below them are the sums of those rankings. As is observed, two methods are better than others if the rankings in different categories are considered. These methods are the weighted average cost and LIFO, because they have sums of 8 and 9, but in the other methods the sums are 14 or 15.

Table 5-10 - Summary of the results of DWAC, IVF, PCA and TSPI

	WAC		**3-month average**		**FIFO**		**LIFO**		**Market price**	
	Average	*Order*	*Average*	*Order*	*Average*	*Order*	*Average*	*Order*	*Average*	*Order*
DWAC	0	1	28544	3	20758	2	74071	5	37244	4
IVF	19543	2	32197	4	28511	3	10448	1	38512	5
PCA	50246	3	56189	4	62759	5	12176	2	6973	1
TSPI	1286	2	0	3	-510	4	8158	1	-1800	5
Sum		8		14		14		9		15

In the following table (Table 5-11) are relative measures (except *TSPI*). In these relative measures, measures in the previous table are compared to inventory, and thus significance is better evaluated. As is observed, in some measures there are clear differences. For example, in relative product costing accurateness (*RPCA*) there is a difference of 14 % between the worst (FIFO, 15,7 %) and the best (market price, 1,7 %).

Table 5-11 - Summary of the results of RDWAC, RIVF, RPCA and TSPI

	WAC		**3-month average**		**FIFO**		**LIFO**		**Market price**	
	Average	*Order*	*Average*	*Order*	*Average*	*Order*	*Average*	*Order*	*Average*	*Order*
RDWAC	0.0 %	1	7.0 %	3	5.3 %	2	19.8 %	5	9.3 %	4
RIVF	5.4 %	2	8.5 %	4	7.8 %	3	3.1 %	1	10.1 %	5
RPCA	12.7 %	3	14.7 %	4	15.7 %	5	3.2 %	2	1.7 %	1
TSPI	1286	2	0	3	-510	4	8158	1	-1800	5
Sum		8		14		14		9		15

However, it is hard to set inventory valuation methods in ranking order by just looking the values in different relative measures. So there has to be developed a measure that takes all of these criteria into account. To circumvent this problem, for *RDWAC*, *RIVF* and *RPCA* there is set a marginal price in measure. These are defined as P_{RDWAC}, P_{RIVF} and P_{RPCA}. For example, marginal price of *RPCA* (P_{RPCA}) can be stated as follows: how much the company is willing to pay now for 1 % decrease in *RPCA*. For the tax shield profit to infinity (*TSPI*) there is no need to submit this kind of marginal price, because it is already in cash.

Based on these marginal prices and actual results in simulations values for each criterion can be formed. These are formed by multiplying actual results and marginal price (except for *TSPI*).

There are negative signs in front of the three first equations because the value of inventory valuation system increases when these measures decrease:

(5.14) $Value_{RDWAC} = -RDWAC \cdot P_{RDWAC}$

(5.15) $Value_{RIVF} = -RIVF \cdot P_{RIVF}$

(5.16) $Value_{RPCA} = -RPCA \cdot P_{RPCA}$

(5.17) $Value_{TSPI} = TSPI$

The objective is to maximize total value of inventory valuation system. Therefore, the sum of these values has to be maximized. The objective criterion, defined as value of inventory valuation system (*VIVS*), is then as follows:

(5.18) $$\begin{aligned} VIVS &= Value_{RDWAC} + Value_{RIVF} + Value_{RPCA} + Value_{TSPI} \\ &= - RDWAC \cdot P_{RDWAC} - RIVF \cdot P_{RIVF} - RPCA \cdot P_{RPCA} + TSPI \end{aligned}$$

The best inventory valuation method is the one that has the largest value of *VIVS*. In the following tables (Table 5-12, Table 5-13, Table 5-14 and Table 5-15) the best methods with certain P_{RDWAC}, P_{RIVF} and P_{RPCA} are presented. Difference between the weighted average cost (criterion described by *RDWAC*) is here case company specific, and even for the case company it is not that important criterion compared to the others. Therefore, the values for P_{RDWAC} can be smaller and they are in the tables 0, 500 €, 1000 € and 2500 €. Inventory value fluctuation due to stainless steel price fluctuation (criterion described by *RIVF*) is more important criterion because it affects the management accounting, and thus the values for P_{RIVF} here are 0, 1000 €, 2000 € and 5000 €. Product costing accurateness (criterion described by *RPCA*) affects product pricing and management accounting and overall it has a larger effect on business than the former two. Thus the values of P_{RPCA} are 0, 1500 €, 3000 € and 7500 €. From the following tables it can be observed that FIFO and 3-month average should not be chosen in any situation. WAC increases its efficiency as P_{RDWAC} increases, and it is not recommended if P_{RPCA} is high. LIFO is recommended if P_{RIVF} is valued high and P_{RDWAC} low. Market prices are recommended if product costing accurateness is essential.

Table 5-12 - The best methods when P_{RPCA} = 0 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	LIFO	WAC	WAC	WAC
	1000	LIFO	WAC	WAC	WAC
	2000	LIFO	WAC	WAC	WAC
	5000	LIFO	LIFO	WAC	WAC

Table 5-13 - The best methods when P_{RPCA} = 1500 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	LIFO	Market price	WAC	WAC
	1000	LIFO	LIFO	WAC	WAC
	2000	LIFO	LIFO	WAC	WAC
	5000	LIFO	LIFO	WAC	WAC

Table 5-14 - The best methods when P_{RPCA} = 3000 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	LIFO	Market price	Market price	WAC
	1000	LIFO	LIFO	WAC	WAC
	2000	LIFO	LIFO	WAC	WAC
	5000	LIFO	LIFO	LIFO	WAC

Table 5-15 - The best methods when P_{RPCA} = 7500 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	Market price	Market price	Market price	Market price
	1000	LIFO	LIFO	Market price	Market price
	2000	LIFO	LIFO	LIFO	Market price
	5000	LIFO	LIFO	LIFO	LIFO

However, in Finland it is not allowed to use LIFO for tax purposes. It is recommended to use FIFO instead of LIFO for tax accounting. (Sillanpää 2008, interview 31.7.2008) Consequently, *VIVS* needs to be modified in the case of LIFO. It is done by letting *TSPI* of LIFO to be as much as *TSPI* of FIFO. In the next tables the best methods under this assumption are presented.

Table 5-16 - The best methods in Finland when P_{RPCA} = 0 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	WAC	WAC	WAC	WAC
	1000	LIFO	WAC	WAC	WAC
	2000	LIFO	WAC	WAC	WAC
	5000	LIFO	LIFO	WAC	WAC

Table 5-17 - The best methods in Finland when P_{RPCA} = 1500 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	Market price	Market price	WAC	WAC
	1000	LIFO	WAC	WAC	WAC
	2000	LIFO	LIFO	WAC	WAC
	5000	LIFO	LIFO	WAC	WAC

Table 5-18 - The best methods in Finland when P_{RPCA} = 3000 with different P_{RDWAC} and P_{RIVF}

		P_{RDWAC}			
		0	500	1000	2500
P_{RIVF}	0	Market price	Market price	Market price	WAC
	1000	LIFO	LIFO	WAC	WAC
	2000	LIFO	LIFO	WAC	WAC
	5000	LIFO	LIFO	LIFO	WAC

Table 5-19 - The best methods in Finland when P_{RPCA} = 7500 with different P_{RDWAC} and P_{RIVF}

	P_{RDWAC}			
P_{RIVF}	0	500	1000	2500
0	Market price	Market price	Market price	Market price
1000	LIFO	Market price	Market price	Market price
2000	LIFO	LIFO	Market price	Market price
5000	LIFO	LIFO	LIFO	WAC

As is observed, the best methods are again the same, WAC, LIFO and market price, as were without the assumption of LIFO not being allowed to be used for tax purposes. Only in a few cases (marked in yellow in table) the best method changes compared to the situation where LIFO is allowed for tax purposes. This implies that tax shield has only little significance in determining the best method.

5.6 Conclusions Based on Simulation Results

Preferred inventory valuation method depends largely on the needs of the management accounting. However, some guidelines can be offered based on the simulation results.

When considering the tax shield, the results are quite surprising. Present values of tax shield benefits are quite close to each other (see *TSPI*, Figure 5-8). The only method which is significantly different in terms of tax shield is LIFO. However, as was mentioned in section 5.5, LIFO cannot be used for tax purposes in Finland. Rest of the methods have only slight differences in their present values. A few thousand euros hardly affect the choice of inventory valuation system, because this amount can easily be wasted in a process of changing current inventory valuation method. Especially if a company is a large multinational company as was in this research. Therefore, it can be concluded that tax shield benefits do not have relevance in choosing inventory valuation method in Finland.

The other criteria were based on inventory fluctuation due to raw material prices (*RIVF*), product costing accurateness (*RPCA*) and difference with weighted average cost method (*RDWAC*) (Figure 5-9). As it was observed, there are major differences in these criteria. There are least differences between different methods in *RIVF*, but still the market price method is seven percent worse than LIFO. This seven percent difference means 30 000 € higher average fluctuation per period in inventory value due to stainless steel prices which is substantial (see difference between LIFO and market price in *IVF*, Table 5-10). Averages of *RDWAC* range from 0 (in WAC) to 19,8 % (in LIFO), the latter meaning 74 000 € contradiction between reported value and value for other purposes. In *RPCA* market price achieves an average as low as 1,7 %, but in FIFO the average is 15,7 %. Thus product costing using FIFO is certainly not accurate, but in market price it is highly reliable. So, all of these three criteria can have significance in choosing the inventory valuation method.

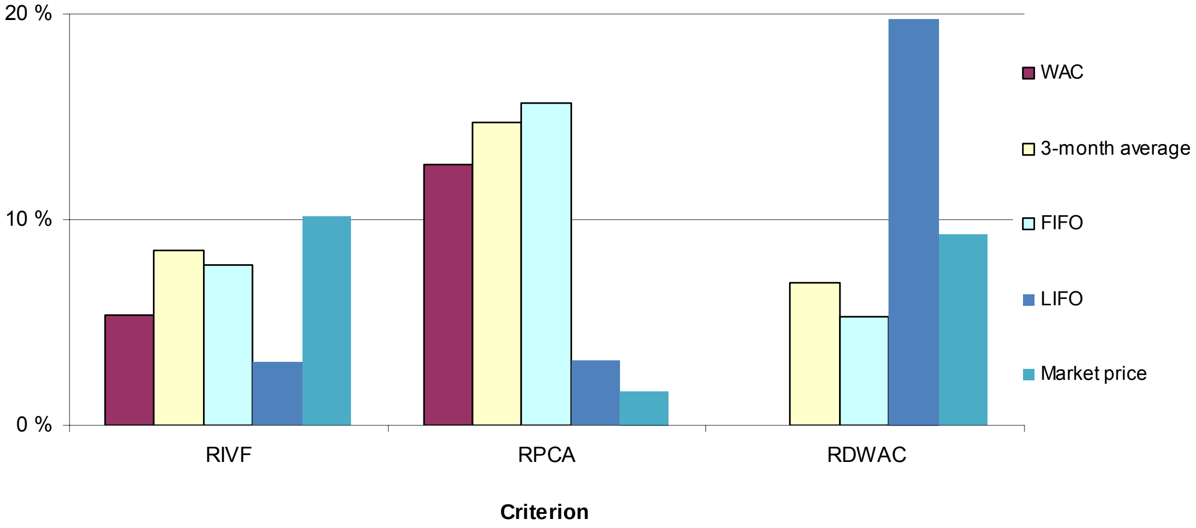

Figure 5-9 - Averages of RIVF, RPCA and RDWAC in simulations

The first thing to do before choosing an inventory valuation method is to consider importances of these different measures. Based on the importances and results in the simulations the best method for a specific company can be obtained. Even though these importances of criteria are company-specific, one important conclusion for the case company is that the case company's current method of 3-month average is not optimal and should be changed. By changing the 3-month average method to another method, improvements presented in the following figure (Figure 5-10) within different criteria are obtained. Improvements in this figure tell how much inventory valuation in specific criterion would improve compared to the 3-month average method, and thus in the figure 3-month average method would have value of 0 in every criterion. The higher the value in a certain criterion, the better the method is in that criterion. In *RIVF* LIFO is the best. In

RPCA market price is the best method and in *RDWAC* WAC is better than others. Also it is observed that WAC is in every criterion better than 3-month average. Therefore, whatever the importances in different criteria are, WAC is preferred method to 3-month average. WAC is also preferred to FIFO. Therefore, FIFO or 3-month average should not be chosen as inventory valuation method whatever the objectives of management accounting are.

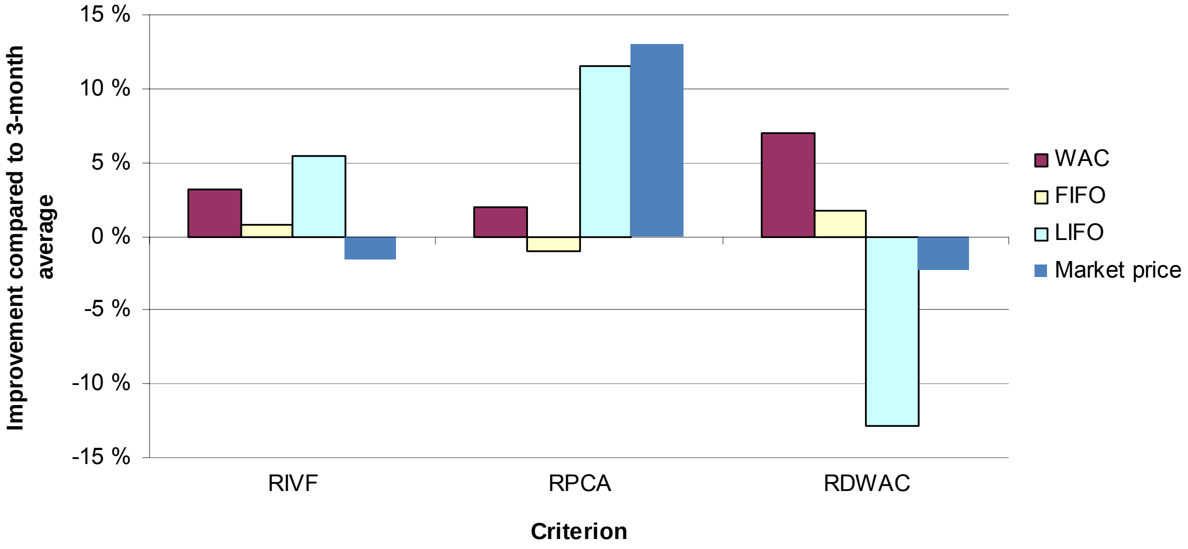

Figure 5-10 - Improvements compared to 3-month average method in significant criterions with different methods

Because FIFO and 3-month average can be eliminated, it is reasonable to compare LIFO, market price method, and WAC, and it is done in the following figure (Figure 5-11). In the figure *Difference compared to WAC* measures how much better the method is compared to WAC in a specific criterion, and thus WAC would get 0 in every criterion. The higher the value in a specific criterion, the better the method is in that criterion. As is observed, all the methods are best in one criterion; LIFO in *RIVF*, market price method in *RPCA* and WAC in *RDWAC*. Therefore, all the methods are weakly pareto-optimal and there is no method that is preferred to some other in all criteria. Thus there the best method cannot be determined without determining importances of different criteria.

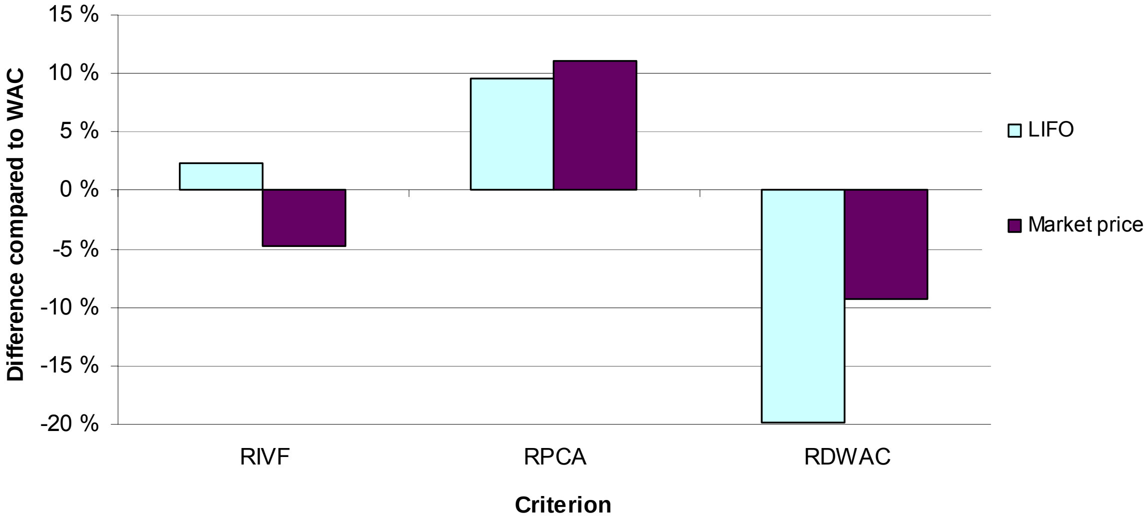

Figure 5-11 - Differences compared to WAC

Even though importances are company specific, there are a few general cases to consider. First of all, the third criterion in previous figure, *RDWAC*, is case company specific. Therefore, it can be assumed that for many companies this criterion is not relevant. If *RDWAC* is not weighted at all and *RIVF* and *RPCA* are both important, then LIFO should be preferred to the market price method and WAC.

Second, if product pricing is especially important and it is based on product costs, then product costing is essential. In addition, if management accounting numbers are not important in decision-making, then inventory value fluctuation is not relevant. In these cases *RPCA* criterion is weighted heavily and other criteria are unimportant. Consequently, market price method is the best method.

Third, for the case company all these measures are important. Thus in choosing inventory valuation method it must be considered how much these different criteria are weighted. After this has been decided, the tables in section 5.5 (Table 5-16, Table 5-17, Table 5-18 and Table 5-19) can be used for determining the best method. Whatever the weights are, the best method is LIFO, WAC or market price method.

5.7 Scenario Analysis

In this section generality and sensitivity of the previous results (see chapters 5.5 and 5.6) are analyzed by scenario analysis. In the simulation model there were two main inputs, which were stainless steel price and raw material flow. In scenario analysis it is examined what would happen to the results in some alternative scenarios. The alternative scenarios tested are presented in the following figure (Figure 5-12). Later these scenarios are referred by the numbers presented in the figure. By these scenarios three hypotheses can be tested in every criterion: (1) raw material flow assumptions have effect on results, (2) raw material price trend has effect on results and (3) raw material price volatility has effect on results. For the material flow there are two different scenarios, namely constant material flow and varying material flow. In constant material flow amount of purchases and production are constant with respect to time, and thus amount of inventory stays constant. Then the effect of price behavior can be better analyzed, because it is the only varying input from the two mentioned. In varying material flow, material flow is the same as was in earlier simulations. When the scenarios of varying and constant material flow are compared, the effect of material flow can be analyzed.

There are three different scenarios concerning raw material price behavior, which are volatile price behavior, upward trend and downward trend in prices. In upward trend a constant 3 % monthly increase in stainless steel prices is set. In downward trend a constant 2 % monthly decrease in stainless steel prices is used. In the volatile prices -scenario the price behavior is the same as in the previous simulations. Comparing volatile prices -scenarios to the upward and downward trends, the effect of price volatility can be analyzed. The ARMA-model (see section 4.3) and regression analysis (section 4.2) used in the earlier simulation model imply that there is only a very small price trend in volatile prices -scenarios, and thus if volatility has no effect on results, the results in volatile prices -scenarios should fall between results in upward trend and downward trend. By upward trend it can be analyzed what happens if availability of raw material decreases and thus prices increase. On the other hand, downward trend is analyzed because there is a possibility that prices decrease, for example, if some innovations come to market. In total there are then six different scenarios, which include the one in earlier simulations (varying material flow, volatile prices). When observing the following results, it must be taken into account that these upward and downward trends are extreme, because they imply 43 % increase (upward trend) or 22 % decrease (downward trend) annually.

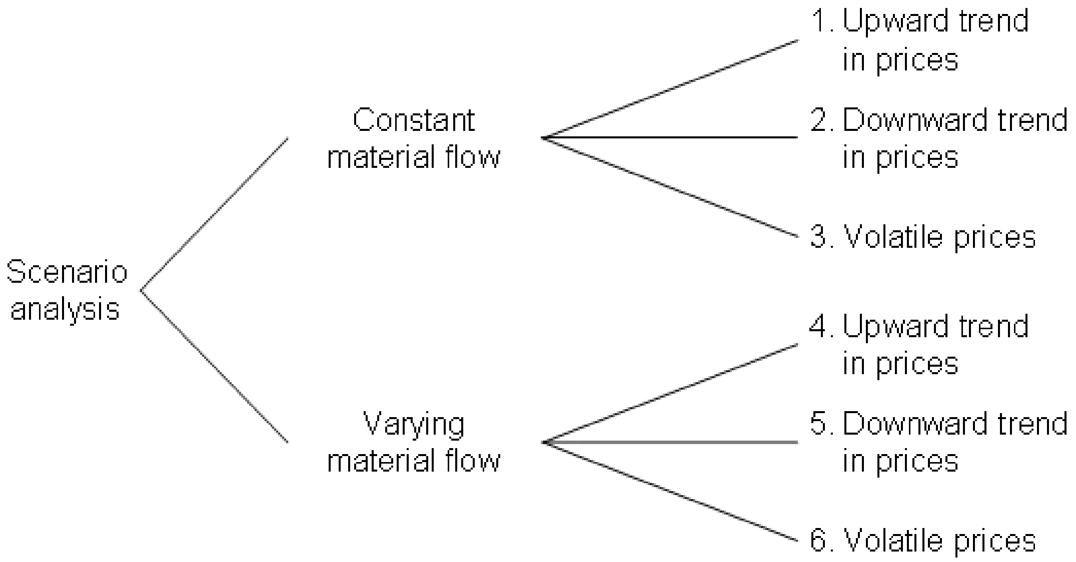

Figure 5-12 - Assumptions in scenario analysis

The first measure to be considered is *RIVF*. In the following figure (Figure 5-13) the averages of *RIVF* in different scenarios and with different inventory valuation methods are presented. The effect of material flow can be analyzed by comparing scenarios with the same price behavior, for example, by comparing scenarios “constant material flow, upward trend in prices” (scenario 1) and “varying material flow, upward trend in prices” (scenario 4). From the figure it can be observed that material flow affects results only a little. The only significant difference is that in LIFO with constant material flow *RIVF* is 0, but it is much more when there is varying material flow. This is because in LIFO the goods in inventory do not change when material flow is constant, in other words, the goods bought will be moved to production right after buying and the original inventory remains the same. When considering the effect of price behavior, it can be observed that both price trend and volatility affect results. For example, if scenarios “constant material flow, upward trend in prices” (scenario 1) and “constant material flow, downward trend in prices” (scenario 2) are compared to scenario “constant material flow, volatile prices” (scenario 3), it can be observed that there are major differences between the first two and the latter one, which confirms the effect of volatility. On the other hand, for example, if scenario “varying material flow, downward trend in prices” (scenario 5) is compared to scenario “varying material flow, upward trend in prices" (scenario 4) it is readily evident that there are significant differences due to trend in prices. So, results concerning inventory value fluctuation (*RIVF*) can be mostly generalized to different material flow alternatives, but not to different raw material price behaviors.

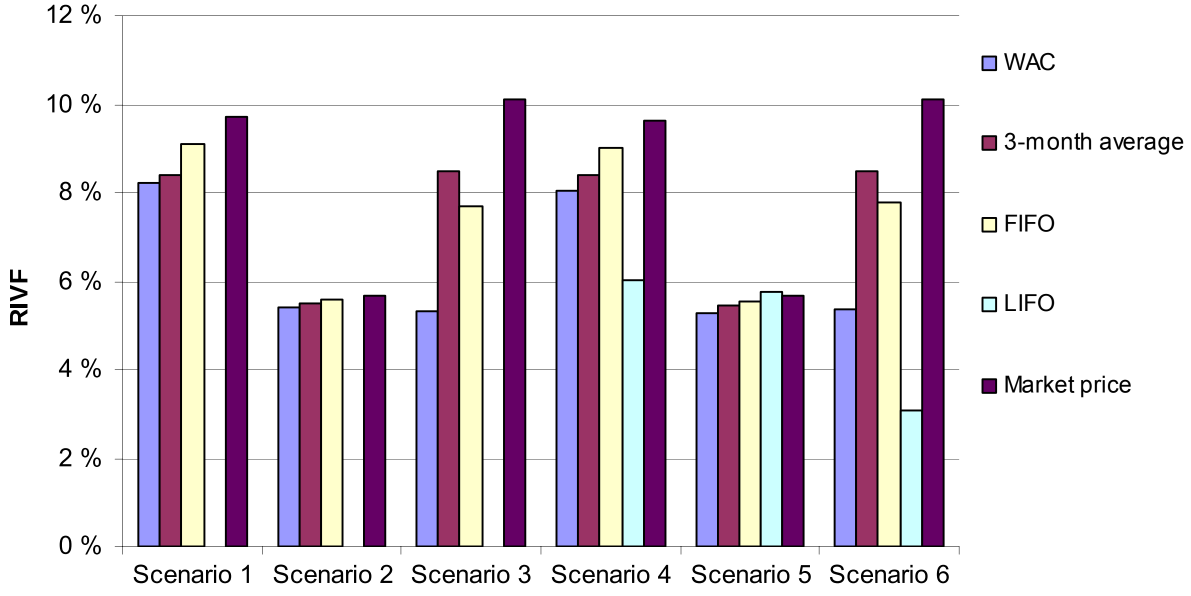

Figure 5-13 - Average RIVF in different scenarios

The second measure discussed here is *RPCA*. From the following figure (Figure 5-14) it is observed that again material flow assumptions have very little effect on results. The only visible difference due to material flow is with LIFO when there is upward trend in prices (compare scenarios 1 and 4). However, again the effect of price trend is significant. In upward trend every method has significantly larger values than in downward trend (compare scenario 1 to scenario 2 and scenario 4 to scenario 5). The scenarios of volatile prices should fall between downward and upward trend, but now they are nearly the same as with downward price trend (compare scenarios 1 and 2 to scenario 3, and scenarios 4 and 5 to scenario 6). So, volatility has also an effect on the results. One interesting thing to note is that the larger upward trend is in prices the worse LIFO is. This results mainly from the fact that in LIFO the oldest units are in the inventory, and those units have the lowest value under upward price trend, and thus the inventory value is low. *RPCA* is a measure which is inversely related to inventory value, and the method that has low inventory value is poor in this measure. All in all, the main conclusion is that material flow does not have a significant effect on results, but the effects of price volatility and price trend are significant.

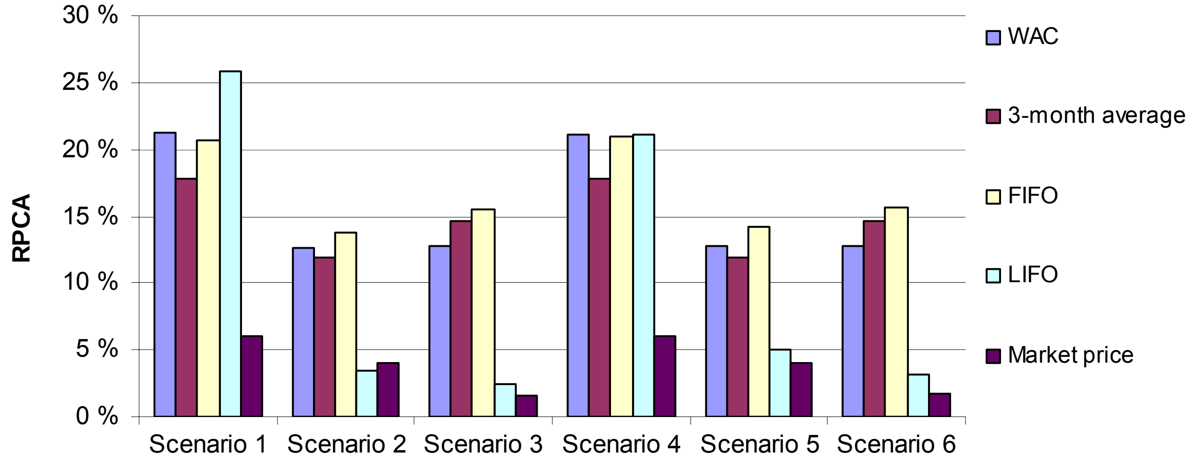

Figure 5-14 - Average RPCA in different scenarios

The third measure is *RDWAC*. The averages in different scenarios of *RDWAC* are presented in the following figure (Figure 5-15). Again it can be observed that the material flow alternatives do not affect results in the other methods except LIFO. The more variation there is in material flow, the better LIFO is in this respect. However, trend in prices affects results because all the methods have the highest values under upward trend. In volatile prices -scenarios the results are much lower than in upward trend but almost the same as is in downward trend, which implies that price volatility affects the results. If price volatility would not affect the results, the values should fall between upward and downward trend.

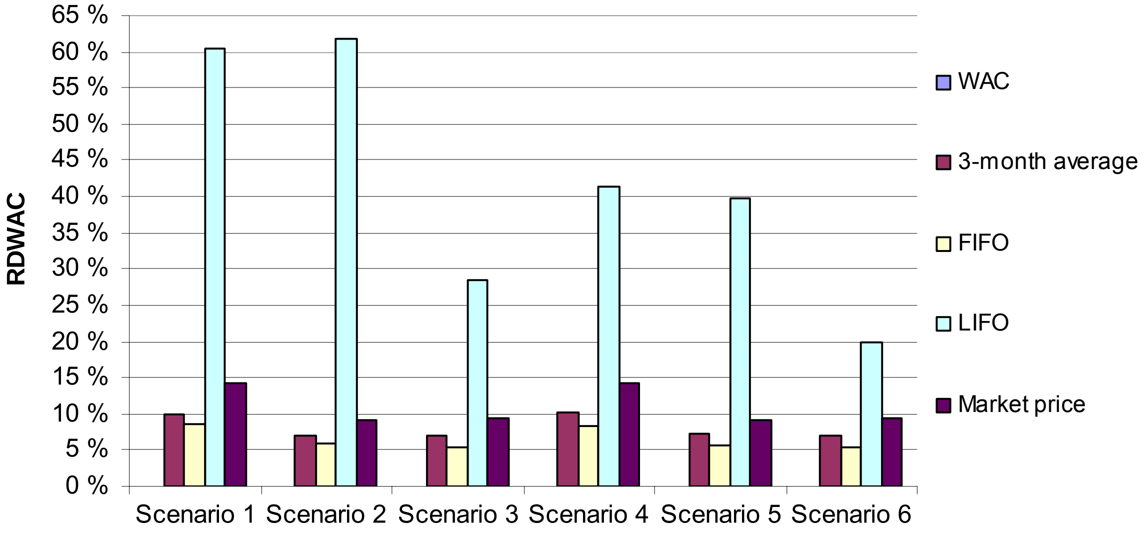

Figure 5-15 - Average RDWAC in different scenarios

The fourth measure is *TSPI* and its averages in different scenarios are in the following figure (Figure 5-16). It was stated earlier that LIFO is not allowed to be used in Finland but now it is assumed that also LIFO could be an option, and that is why it is taken into account here. As is observed, price trend clearly affects results. In LIFO the difference between upward and downward price trend is huge, almost 500 000 € when material flow is constant. Also in other methods the price trend effect is significant. Volatility of prices also clearly affects the goodness of every inventory valuation method. The effect of material flow is significant in LIFO and slightly significant in WAC and FIFO. So when present value of tax shield is considered, price volatility, price trend and material flow volatility are all significant.

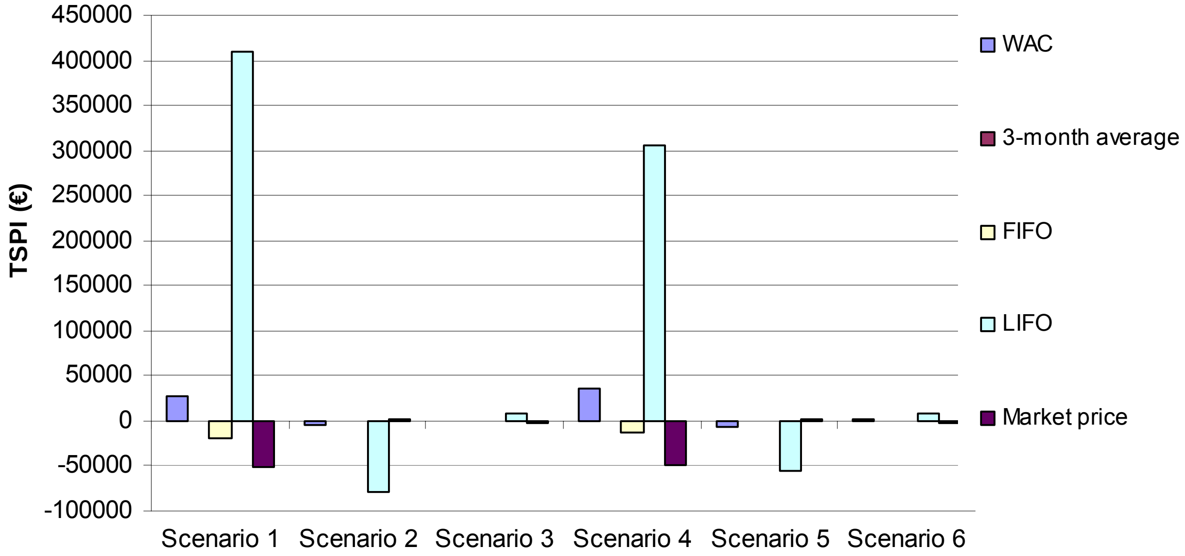

Figure 5-16 - Average TSPI in different scenarios

Previously the significance of price volatility, price trend and material flow volatility overall were examined. However, from the previous analysis it is possible to make some rough guesses of how different methods would manage if price volatility, price trend or material flow volatility would change compared to the initial situation in simulations. In the following table (Table 5-20) there are evaluations of how relative performance of an individual inventory valuation method changes if some of the three factors increases. The effect of factors decreasing is obviously reversed. The relative performance of an inventory valuation method here means performance compared to the other methods. The evaluations are obtained by comparing change in goodness of inventory valuation method when one factor changes and others remain constant. For example, the effect of price trend increase is obtained by observing what happens when downward price trend is changed to upward price trend. Overall values in the table are obtained by summing + signs and deducting - signs.

Table 5-20 - The effect on relative performance of inventory valuation methods if price volatility, price trend or material flow volatility increases

	RIVF			RPCA			RDWAC			TSPI			Overall		
	PV	PT	MFV	PV	PT	MFV	PV	PT	MFV	PV	PT	MFV	PV	PT	MFV
WAC	+			+						-	++		+	++	
3-month average	-							-					-	-	
FIFO								-		+	-		+	- -	
LIFO	++	++	- - -	++	- - -		+++		++		++++		7+	3+	-
Market prices	- -			++				- -		+	- - -		+	5 -	

PV = Price volatility increases
PT = Price trend increases
MFV = Material flow volatility increases
+ / - = Slight improvement / weakening in relative performance
++ / - - = Clear improvement / weakening in relative performance
+++ / - - - = Large improvement / weakening in relative performance
++++ / - - - - = Remarkable improvement / weakening in relative performance

As is observed from the previous table, LIFO has an improvement in relative performance when price volatility or price trend increases. The goodness of market price method decreases if price trend increases. Otherwise the changes in relative performances are quite small. However, if there are large changes in future concerning price trend, price volatility and material flow volatility, then evaluating changes in relative performances is essential. Interesting is that material flow volatility affects relative performance only in LIFO, and even in LIFO only in two criteria which are *RIVF* and *RDWAC*. Therefore, it can be concluded that material flow assumptions have only a small effect on the efficiency of inventory valuation methods. Thus the results of this research can be mainly generalized to various raw material flow environments. Stainless steel prices are almost the same for all companies, and thus material flow is the only input that depends on the case company in this empirical study. This makes it possible to generalize the results of this research to other companies.

6 Conclusions

In the literature review it was observed that product costing and inventory valuation are left uncovered from the viewpoint of fluctuating raw material prices, even though these two topics are largely covered even from mid 20th century from a number of viewpoints. Uncertainty of raw material prices affects every objective of management accounting, which are supplying information for internal decision makers, facilitating their decision making, motivating their actions and behavior in a given direction and promoting efficiency of the organization. All previous objectives are heavily affected by this uncertainty, and thus it has a large impact on business performance. Another gap in the current research is that overall situation of a company in choosing inventory valuation and product costing policies has not been analyzed thoroughly. Most of the researches focus on just one or a few factors that affect the choice of inventory valuation policies.

Due to these gaps in the current research, this research focused on analyzing efficient inventory valuation and product costing policies under fluctuating raw material prices. To analyze these methods as broadly as possible, a case company was chosen for this research. This research included a literature review and an empirical study. The research method in the empirical study was simulation, which was observed to be the best method for analyzing the effects of random movements in raw material prices in the future. Various scenarios can be tested by simulation, and based on these scenarios the best methods can be determined through versatile measures.

A brief summary of research progress is presented next, where the main parts of this research are discussed. After the summary, integral results of this research are covered. In final part topics for further research are discussed.

6.1 Summary

First an extensive literature review was carried out in order to analyze inventory valuation and product costing in depth. The focus was on how a company should choose inventory valuation and product costing policies. Due to raw materials being an important part of this research, also the modeling of raw material prices was covered.

Despite the fact that inventory valuation and product costing have been researched for so long, there is no consensus of the best methods. Researchers have been debating especially which one of the following two is better: last-in first-out (LIFO) or first-in first-out (FIFO). Some researchers argue that FIFO is the best method, for example, when there is a possibility of manipulating accounting figures or a company has a high debt ratio. On the other hand, LIFO is recommended when tax shield benefits can be significant or when pricing is based on product costs. In order to create an overall view of all the valuation methods, large amount of research papers were covered to form a list of factors that should affect the choice of inventory valuation method. This list should be considered as a general guideline when choosing inventory valuation method.

To take fluctuating raw material prices into consideration, an empirical study including the effect of fluctuating raw material prices was made. Thus literature review included practices and principles of modeling and forecasting raw material price movements. There are various models that predict random movements in raw material prices. Maybe the best-known models are moving-average and exponential smoothing. According to literature, an efficient method is autoregressive moving-average (ARMA), which takes previous values (autoregressive part) and previous errors (moving-average part) into account. For estimating volatility autoregressive conditionally heteroskedasticity (ARCH) and generalized autoregressive conditionally heteroskedasticity (GARCH) models are recommended. The best methods of forecasting actual values and volatility still depend on the situation. For example, lack of data can be a problem when forming complicated models.

Based on the literature review, a research framework for the empirical study was constructed. The framework included three main variables that should affect the choice of raw material inventory valuation and product costing policy: (1) how well information reflects company's performance, (2) effect on tax obligations and (3) product costing accurateness. Based on the framework, evaluation criteria to evaluate different inventory valuation methods were constructed. These criteria included present value of tax shield, inventory value fluctuation due to stainless steel price, product costing accurateness and difference in inventory value compared to inventory value of weighted average cost. The first three criteria were derived directly from the variables in the research framework. The fourth criterion was based on the situation in the case company.

To evaluate different inventory valuation methods based on the formed criteria, a simulation model was built taking the overall situation of the case company into account. The main variable in the simulation model was stainless steel price, which depends on nickel price. Thus nickel price behavior was modeled. In addition, purchasing and production behavior were modeled for the simulation model. Five different inventory valuation methods were tested which were FIFO, LIFO, weighted average cost (WAC), market price and 3-month average. The first four were found to be suitable for raw material accounting based on the literature and the last one was used in the case company.

After simulations the results based on the evaluation criteria were formed in order to evaluate the different methods. Since there were in total four criteria, and different companies appreciate these criteria differently, a comprehensive sensitivity analysis considering various appreciations of these criteria was done. Also, in order to analyze inventory valuation methods in different situations a scenario analysis was done.

6.2 Integral Results

The research problem of this study was stated as follows: *How should raw material flow around raw material inventory be valuated?* The main results of this research are presented in this chapter. These results are based partly on the literature review but mainly on the empirical study. The results are conducted with respect to the research objectives stated in the introduction chapter.

The first research objective was to model stainless steel price behavior. To this end, it was investigated whether stainless steel prices depend on any other variables. Based on regression analysis, stainless steel prices depend primarily on nickel prices one, two and three months ago. Therefore, nickel prices were modeled. In the literature review it was observed that autoregressive moving-average forecasting method is a versatile method to model raw material price movements. In the analysis it was found that future nickel prices depend only on the previous nickel prices when monthly values are modeled. So autoregressive process of lag one (AR(1)) was chosen for further analysis. Also volatility of nickel prices was analyzed and it was found that volatility doesn’t depend on the previous volatilities. Consequently, constant variance was chosen to model variance of nickel prices.

The second research objective was to find out factors that determine the best raw material inventory valuation and product costing policy. It was observed that there are eight main factors that should be taken into account when choosing inventory valuation policy, and they are (1) complexity of IT-systems, (2) how much pricing is based on product costs, (3) how probable is manipulation of accounting measures, (4) restrictive debt covenants, (5) debt ratio, (6) potential tax savings, (7) firm size and (8) volatility of earnings. By these factors inventory valuation methods overall can be evaluated. However, this research was about valuating raw material inventory, and thus based on these factors raw material inventory valuation method cannot be straightforwardly determined.

The third research objective was to find out the most efficient way to value raw material inventory. In the literature review it was observed that this objective is highly related to the fourth research objective, which was to discover the most efficient way to value raw material flow out of inventory. The reason for this is that the same method has to be used for both raw material inventory valuation and product costing purposes. Thus these two objectives were analyzed together. In the simulation model five different raw material inventory valuation methods were analyzed by evaluation criteria. Overall, last-in first-out (LIFO), weighted average cost (WAC) and market price method turned out to be very promising. LIFO was best in two criteria, which imply that tax shield benefits are high and inventory value is nonvolatile in LIFO. Weighted average cost was in top three in every criterion, and thus it was the most consistent in this sense. Market price method is especially good for product costing. Surprisingly, FIFO and current method in the case company (3-month average) should not be used for raw material accounting in any situation. Changing the current method would yield high improvements. For example, changing to LIFO would decrease product costing error from 14,7 to 3,2 percent of product costs and inventory value fluctuation due to stainless steel price from 8,5 to 3,1 percent of inventory value. The choice between LIFO, market price and WAC depend on the objectives of inventory valuation because all these measures are weakly pareto-optimal.

The results of this research contribute well to the previous research around inventory valuation and product costing. As mentioned, inventory valuation and product costing, when raw materials are considered, are not even nearly completely covered, although there does exist research around these topics from mid 20th century. Especially there does not exist a research that covers these two topics under volatile raw material, and thus this research fills a major gap in current research. From the viewpoint of companies that struggle with volatile raw material prices this research can be an important asset when considering how to improve raw material inventory valuation and product costing. Also, the simulation model of this research can easily be extended to other raw materials. For example, oil prices have been volatile in recent years and extending this simulation model for oil could be worthwhile.

6.3 Further Research

The objective of this research was to investigate how to value raw material flow around raw material inventory. This research succeeded well in meeting its objectives defined in the introduction of this research (see chapter 1.2). However, in the area of this research a lot more further research is needed. Especially the following two topics need to be researched further.

The raw material in this research was stainless steel. Stainless steel prices are dependent on nickel prices, and the relation was modeled with regression analysis. The regression analysis itself limits generality only a little. Some additional error still exists due to the fact that the parameters of the model are let to vary in some extent in the simulation model. However, primarily the results of this research can be generalized to raw materials that have similar price behavior as nickel has. Nickel prices behave as AR(1)-model. In the scenario analysis (see chapter 5.7) it was observed that the results of this research cannot be generalized to other kinds of price behaviors. Therefore, one topic for further research would be conducting this research for raw materials that have price behavior different than AR(1)-model.

This research focused on raw materials and therefore semi-finished and end-products were set to be beyond the scope of this research. The methods here were chosen to be consistent with raw materials, and thus these results cannot be generalized to semi-finished or end-products. End-products often form the largest share of inventory value. Thus it would be interesting to investigate how these results differ if end-products are the focus of research.

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