Valuing Customer Portfolios under Risk-Return-Aspects: A Model-based Approach and its Application in the Financial Services Industry

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EXECUTIVE SUMMARY

For identifying and selecting the most profitable customers in terms of the shareholder value, the Customer Lifetime Value (CLV) gained broad attention in marketing literature. However, in this paper, the authors argue that the CLV does not take into account the risk associated with customer relationships and consequently does not conform to the principle of shareholder value. Therefore, a quantitative model based on financial portfolio selection theory is presented that considers the expected CLV of customer segments as well as their risk. The latter includes the correlation among the segments. It is shown how imperfect correlation among segments may be employed to maximize the value of the customer portfolio. Since portfolio selection theory does not allow for the consideration of fixed costs, it is extended by a heuristic method consisting of two algorithms, referred to as "subtract"- and "add"-approaches.

Keywords: customer profitability, customer portfolio, customer segment valuation, financial services industry

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INTRODUCTION

In competitive economies, the main goal of every company is to maximize its shareholder value (Lumby and Jones 2001, pp. 4 ff). The shareholder value is based on the concept of net present value (NPV), which reflects the expected long-term profitability of a company. Many authors, e.g. Gruca and Rego (2005), Gupta, Lehmann and Stuart (2004) and Hogan et al. (2002), argue that the basis of a company's profitability is constituted by its customers. Hence, the increase of shareholder value requires first the increase of customer value (or as Rappaport noticed "(…) without customer value there can be no shareholder value" (Rappaport 1998). This insight led to some fundamental changes in marketing theory as well as in corporate practice towards a customer-centric view and the emergence of Customer Relationship Management (CRM). CRM focuses on the valuation, selection and development of enduring customer relationships and on the allocation of limited resources to maximize the value of a company. For identifying the most profitable customers, various valuation methods have been developed in theory and practice. Customer valuation gained wide acceptance in particular in the financial services industry: according to a survey of Mummert Consulting, comprising 80% of German insurance companies, the increase of customer value and customer loyalty has high priority in strategic management (Forthmann 2004). A study in the banking industry at the University of Muenster reveals that 100% of the investigated banks consider customer value management as an instrument to increase returns (Ahlert and Gust 2000).

A customer valuation concept that is (at first sight) compatible with the principle of shareholder value is the Customer Lifetime Value (CLV). It has gained broad attention in the marketing literature (cf. Woodall 2003). The CLV takes into account all expected future cash in- and outflows of a customer and calculates their NPV. Although marketing literature discusses the concept of CLV in detail, it still lacks practicability, since the estimation of future profitability is uncertain and thus involves the risk of bad investments. The consideration of risk, i.e. the deviation of cash flows from their expected value, is therefore crucial for a risk averse decision maker, but still remains fairly disregarded in customer relationship valuation (Hopkinson and Lum 2001).

We can benefit from existing financial theory concepts if future cash flow risk is to be taken into account: capital markets investors hold portfolios consisting of different asset classes with different risk-return profiles for balancing losses. Although the differences between customers and financial assets with respect to the process of their valuation, acquisition, and retention behavior are clear, both of them reveal similar characteristics. This allows transferring financial theory concepts (e. g. Capital Asset Pricing Model (CAPM), Portfolio Theory and Real Options) to support customer valuation decisions (as shown by Cardozo and Smith 1983; Dhar and Glazer 2003; Fader et al. 2005; Haenlein et al. 2006; Hogan et al. 2002; Johnson and Selnes 2004; Levett et al. 1999; Ryals 2001; Ryals and Knox 2005l Slater et al. 1998). For the purchase and acquisition of both financial assets and customers, investments have to be made. Therefore, it is rational to buy and acquire financial assets and customers respectively, if the expected cash inflows from financial assets or customers exceed cash outflows of the transaction or acquisition. However, as with financial assets, some customers may offer a substantial CLV, but at the same time their cash flows may be unsteady and therefore more risky, whereas the CLV of others may be comparatively smaller, but more constant (Ford et al. 2003, p. 83). Due to those similarities, customers can be regarded as risky assets, too (Hogan et al. 2002). Accordingly, valuation techniques not only have to consider the profitability of a customer segment, expressed by the CLV, but also the associated risks. Such risks do exist during the whole customer life cycle. If a firm wants to attract many customers in the acquisition process, several customer relationships are perhaps not valuable (like with "cherry picker" customers) and thus, investments to acquire these customers are not profitable at all. For instance, the financial service

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provider we consider in our case study acquires customers (academics) at the end of their studies (right before final exams) and supports students by giving them advice for their applications (application documents, etc.) or by providing trainings for their application assessments. Thus, the provider invests into the relationships without knowing their future development and value in detail. If a student does not make his/her career as initially predicted, these investments are lost, i.e. only a few or no cash inflows are generated by the customer in the future. If this applies to many customers, these risks have to be considered as a higher deviation of the expected CLV of a customer segment. Such risks also exist within the growth and penetration stage of relationships. This means that a customer may entirely switch to a competitor or he/she may establish relationships to more than one firm. Both have impact on the duration and intensity of customer relationships which has again direct impact not only on the expected CLV but also on the risk of a customer segment. Since firms want to generate the highest cash inflows within this stage, risks - especially exogenous (given) risks, which are, for example, based on economical (cyclical downturn) or competitive changes (new competitors join the market) - have to be considered. Mostly, such changes can not be prohibited by firms. However, firms have to manage these exogenous risks, i.e. they should think about adding customers and customer segments to the customer base, which - compared to other segments - generate lower but steadier cash flows during their lifecycle and are more independent, for example, from cyclical downturns. Furthermore, the stages of relationship reactivation and recovery include risks too, primarily the risk that investments are not profitable. If the probability is high that many customers in spite of investments migrate to competitors both expected CLV of a customer segment and risks (higher deviation of the expected CLV) are affected. Thus the firm has to identify for which customers it is reasonable to invest in - or not to take the risk of a “lost investment”. Such aspects which are mentioned exemplarily here have impacts on the expected CLV, the related risks and thus profitability of a customer portfolio.

Moreover, traditional customer valuation concepts often concentrate on assessing individual customers (Hogan, Lemon, and Libai 2003). Thereby, they neglect the fact that the risk of customer portfolios may be diminished by selecting customers with varying cash flow structures (Dhar and Glazer 2003). Hence, the main objective of CRM should be to determine and value the customer base as a whole (and not only individual customers).

In this paper we present a model for the composition of a customer portfolio, consisting of different customer segments. The model is based on the financial portfolio selection theory of Markowitz (Markowitz 1952. 1959). It considers the reward of assets (customer segments) on the one hand and the risk associated with them on the other. The risk of assets includes their individual risk (denoted as deviation of expected cash in- and outflows of a customer segment) as well as their correlation with each other. The Markowitz algorithm, however, excludes the existence of fixed costs, which may play an important role in the context of valuing customer segments and customer portfolios, as we will see. Some papers in financial portfolio optimization present algorithms for the incorporation of transaction costs that occur when purchasing or selling assets, e.g. Best and Hlouskova (2005) or Kellerer, Mansini, and Speranza (2000). However, the number of decision variables increases drastically with transaction costs and the optimization problem becomes even NP-complete in the case of fixed transaction costs. Therefore, we present a heuristic approach in the paper at hand that allows finding a solution to the portfolio optimization problem in consideration of fixed costs, which arise with customer relationships, for a manageable quantity of customer segments.

The paper is organized as follows: the next section gives a short overview of recent approaches in customer valuation considering the expected CLV of customers as well as their risk. Subsequently, we present our customer portfolio model. In a first step, we test an already existing customer base for efficiency and optimality (in terms of the Markowitz portfolio selection theory). In a second step, we derive the value of new customer segments for a customer portfolio. In this case, we have to consider the fixed costs of the new segments, which require the development of the heuristic method. The conceptual decision model is followed by the application of the approach, illustrating implications for strategic marketing. Finally, the results of the paper are summarized and directions of further research are discussed.

RECENT RISK-RETURN-APPROACHES IN CUSTOMER VALUATION

If future cash flows were known with certainty, i.e. in a deterministic world, the valuation of the customer base and of its contribution to shareholder value would be rather simple: the NPV of the customer base would be the aggregation of the cash flows (cash inflows minus cash outflows) of the single customers, discounted by the risk-free rate. Hence, in order to maximize shareholder value, the cash flows of the individual customers would have to be maximized. However, although most research in the area of customer valuation does not explicitly differentiate between the deterministic and stochastic world, it is generally agreed that cash flows depend on several factors that may cause deviation from forecasts and are therefore uncertain. Srivastava, Tasadduq, and Fahey (1997) classify these risk factors into three groups: external factors may be of macroeconomic nature, like technological, political, regulatory, economical or social changes. Furthermore, changes in the competitive environment of the company affect customer behavior and in turn cash flows. For example, competitors may launch new products, change product pricing, or use new distribution channels. Finally, marketing actions of the company itself in product and service development, distribution, pricing, and advertising and promotion may have an impact on cash flows (see also Hogan et al. 2002; Ryals 2005; Venkatesan and Kumar 2004). However, in this paper we will focus especially on the first two groups of (exogenously given) risk factors, since they cannot be influenced directly by the company itself and therefore are harder to be balanced in contrast to the last group. Furthermore, we focus on exogenous risk factors, since these factors have been paid less attention in scientific literature too. A good example of the importance of these risks is the big slump of incomes in the information technology sector and related sectors (e.g. information technology consulting) due to the crash of the internet economy some years ago. Companies focusing on customers in these sectors got in trouble because their cash inflows decreased together with the decreasing incomes of their clientele (cluster risks), too[1]. Therefore, these risks should – among other measures – be diversified for optimizing the customer portfolio under risk-/return-aspects. Such a diversification can also be accomplished for different, potential strategic programs and decisions (e.g. entry in a new market or developing a new product; cf. Woodruff 1997) of the company itself. If a firm develops, for instance, two alternative strategic programs based on their business and marketing objectives (for the stages in the traditional planning process of marketing management see Brassington and Pettitt (2006)), it has to estimate the impact on cash flows of each customer segment (e.g. additional expected cash inflows within the new market) as well as risks (e.g. in the sense of the deviation of the expected cash flows) of both programs in a subsequent step. Given such programs and estimations, we focus on valuing and optimizing the customer portfolio for each program taking into account different customer segments and their risk-return-profile.

Since the future profitability of customers and customer segments is uncertain, risk averse marketers will request a minimum rate of return for investing in such risky "assets." Some authors therefore propose the usage of the weighted average cost of capital (WACC) of a company as minimum rate of return. They argue that the WACC, which is computed as the cost of debt multiplied by the proportion of debt funding and the cost of equity multiplied by the proportion of equity funding, reflects the true cost for the company to get money from financial markets (Lumby and Jones 2001, pp. 419 ff.). Since customer segments may be seen as risky assets, too, it is claimed that the WACC may be used as discount rate in the CLV (Kumar, Ramani, and Bohling 2004; Hogan et al. 2002). Only if the return of a customer segment exceeds the costs of capital, the segment creates shareholder value (Ryals 2002).

However, for accepting a customer segment that increases risk in the portfolio, it is argued that one demands a higher return and the cost of capital rises. This means that decision makers are supposed to be risk averse. In consequence, a constant discount rate of the WACC in CLV calculation does not reflect the customer segment-specific risk in a proper way. Riskier customer segments are overvalued and segments providing lower but steadier cash flows during their lifecycle are discriminated against. Hence, it is emphasized that the WACC has to be adjusted to the individual risk of a customer segment by setting it higher the more a segment contributes to the risk of the whole customer base. The research in recent

[1] Since cash outflows like e.g. costs of personal, information systems or buildings could not been reduced to the same extent, the cash flows and thus the CLV decreased as well.

CRM literature shows that the CAPM of financial portfolio theory is mainly proposed and used to calculate a risk-adjusted discount rate in customer valuation (Dhar and Glazer 2003; Gupta, Lehmann and Stuart 2004; Hogan et al. 2002; Hopkinson and Lum 2002; Ryals 2001).

The CAPM is based on the assumption that investors are risk averse, i.e. they ask a larger reward for carrying higher risk. Furthermore, it implies that all assets carry two different types of risk that have to be distinguished: systematic and unsystematic risk. The systematic part is market-wide and therefore affects all assets. Examples are changes in interest rates, incomes, business cycles, etc. The unsystematic part of risk, however, is related to a single asset or a limited number of assets. The CAPM shows that it can be eliminated by holding a well-diversified portfolio, whereas the systematic risk cannot be diversified away. Hence, investors require a risk premium for accepting it. The systematic risk of assets is not measured by the variance of return, but by its covariance with market return. The ratio of the covariance between asset and market and the variance of the market reveals the "Beta value" of the investment. The Beta of the market is equal to one, an asset being riskier than the market has a Beta larger than one, and a less risky asset a Beta smaller than one. Furthermore, the CAPM assumes the existence of a risk-free investment. Investors hold a combination of the risk-free asset and the market portfolio, which is a portfolio consisting of all risky assets available, with each asset held in proportion to its market value relative to the total market value of all asset. It depends on their individual risk aversion how much they actually invest in the risk-free asset. Furthermore, if we use the term "market portfolio" in the meaning of the *one* market portfolio for all investors further assumptions are necessary. First, all investors have the same investment opportunity set (i.e. for example each company can acquire, maintain and enhance the same customer segments). And second, all investors have homogeneous expectations about the risk-return-profile of each investment opportunity (i.e. each firm has homogeneous expectations about the risk-return-profile of each customer segment being in the opportunity set). We come back to this aspect in the following.

With the help of the CAPM, we may determine the return of each risky asset being part of the market portfolio in the equilibrium of capital markets. It is a combination of the premium for accepting the systematic risk associated with the risky asset and the return on the risk-free asset. The relationship between systematic risk and return for each risky asset is linear and may be given by the security market line (SML) in (2.1) (Copeland, Weston, and Shastri 2005, pp. 151):

$$E(r_i) = r_f + \beta_i \cdot (E(r_m) - r_f), \tag{2.1}$$

where $E(r_i)$ is the expected return on investment i, β_i denotes the systematic risk of asset i. r_f represents the risk-free rate of return, whereas $E(r_m)$ refers to the expected return on the market portfolio.

It is argued that the SML may be used to adjust the specific WACC of any risky investment alternative, i.e. also in the context of relationship valuation. For this reason, the Beta value of a customer segment reflects the systematic business risk of the segment and the systematic financial risk of the company itself (Lumby and Jones 2001, pp. 424 ff.). Consequently, the NPV of the customer segment would be (under the assumption of time invariant costs of capital) given by the expected cash flows, discounted by the segment-specific risk-adjusted WACC ($CF_{t,i}^{in}$ denotes the cash inflows of customer segment i in period t, whereas $CF_{t,i}^{out}$ represents the corresponding cash outflows):

$$CLV_i = \sum_{t=1}^{T} \frac{CF_{t,i}^{in} - CF_{t,i}^{out}}{(1 + r_f + \beta_i \cdot (E(r_m) - r_f))^t}. \tag{2.2}$$

The higher the risk of a customer segment, the higher the rate of return shareholders will require for investing in that customer segment. The SML of equation (2.1) at a Beta of one reflects the average WACC that may be mapped in a risk-return-diagram. Ryals (2001; 2002) argues that, according to their specific Beta, some of the customer segments will lie below the average WACC in the diagram and hence destroy shareholder value, whereas others will be above the average, creating shareholder value.

To calculate the value of the customer base as a whole, the CLV_i of the individual customers may be aggregated since the Beta values for all assets are linearly additive (Copeland, Weston, and Shastri 2005, p. 153). Therefore, the CAPM allows first of all for the determination of the customer value on an individual level, wherein the return and the risk of a customer are taken into account. Furthermore, the value of the customer base and its contribution to shareholder value may be derived.

However, the CAPM shows some drawbacks in the context of valuing customers and customer segments that will be outlined briefly (see also Hogan et al. 2002):

(1) First of all, the calculation of the Beta value of customer segments requires the definition of the market portfolio which - as mentioned above - is the portfolio consisting of all assets available, with each asset held in proportion to its market value relative to the total market value of all assets. Since all companies or marketers in general do not have homogeneous expectations about the risk-return-profile of each customer segment (e.g. because each company manages its own customer relationships at the moment of the decision, i.e. two companies estimate the risk-return-profile of the same customer segment differently), the determination of *one* market portfolio for all companies is very difficult or often not possible at all. As a result, Ryals (2001) as well as Dhar and Glazer (2003) define the market portfolio in the area of CRM as the company's current customer base. Taking the company's current customer base as market portfolio is theoretically appropriate only if the value of an already existing customer portfolio should be analyzed and therefore all required data exist (restrictive case). However, the application of CAPM in relationship management seems to be difficult, if decisions should be taken about adding or deducting a customer segment to or from the existing portfolio. The risk premium for the market - and thereby for the customer base - must remain constant for determining the segment-specific risk (Huther 2003, p. 127). Changing the composition of the customer portfolio by adding or subtracting a customer segment will change its return and thus its risk premium as well as the variance of return, though. Without knowing the variance of the market portfolio, the Beta value of the new customer segment cannot be determined. However, the Beta is crucial to adjust the WACC for risk in the calculation of the customer segment-specific CLV. So, the determination of the market portfolio as well as the Beta value – which reflects the systematic risk – is really difficult in the context of valuing customer segments. Additionally, even if we correctly determine both the market portfolio and the Beta value, the current customer base is a result of self-selection by customers, too. Thereby it will not reflect a completely diversified and risk balanced portfolio in the sense of CAPM. Therefore, the CAPM is practically not applicable. Another shortcoming of the CAPM is – as mentioned – the assumption of homogeneous expectations of all marketers. This assumption is crucial for the existence of the market portfolio and the equilibrium on capital markets (Copeland, Weston, and Shastri 2005, p. 148). The equilibrium on capital markets, on the other hand, requires that all investment alternatives are part of the market portfolio with their correct market price (Huther 2003, p. 130). Translated into the customer valuation context, this requires that the values of all customer segments have to be given for determining the value of the customer base, which again is a prerequisite for the valuation of the different customer segments. Considering this, CAPM is not an adequate method for valuing customer portfolios.

(2) In addition to these conceptual drawbacks, the exclusive consideration of the systematic risk related to the Beta value of a customer segment implies that the risk averse decision maker can completely diversify the unsystematic risk away. This assumption requires that, in case of an unforeseeable event (e.g. recession, inflation or the crash of the dot.com marketplace a few years ago), only one or a very limited number of customer segments are affected. Their cash flow deviation may be then balanced by the steady cash flows of other segments,. Therefore, the cash flows of different segments have to be negatively correlated. As we discussed at the beginning of this section, cash flows depend on several factors that may influence each customer segment to a different extent. On the whole, however, their cash flows will tend to move in the same direction, i.e. correlation might be imperfect but positive (Ryals 2001). In consequence, the correct determination of the riskiness of a customer segment has to consider the systematic as well as the unsystematic part of risk. Hogan et al. (2002) argued in the same way by discussing the drawback of customer valuation models and CAPM to in-

corporate the influence of environmental effects (e.g. macroeconomic changes, impact of competition). For instance, they described that "during recessions, customers become more price sensitive" (Hogan et al. 2002). This circumstance reduces among other things size of wallet but not for each customer and customer segment to the same extent. I.e. that the size of the wallet of different customer segments within a portfolio are correlated. Such unsystematic risks can cause serious cash flows and profit collapses. However, CAPM does not consider unsystematic risks which make it hard to use in the context of customer segment valuation.

(3) With the assumption of completely diversified portfolios, the CAPM furthermore ignores the fact that even with positive but imperfect correlation, marketers may profit from risk diversification. Since customer segments do not react in exactly the same way on exogenous factors, the risk of a portfolio may decrease. In consequence, portfolio value may be increased.

Summing up, we state that the issue of risk in the context of relationship valuation is addressed only in a few research papers. To the best of our knowledge, none of them explicitly defines the risk preference of the decision maker. This is, however, a prerequisite for an appropriate consideration of risk in customer valuation. If a marketer is for example assumed to be risk neutral, the risk of deviating cash flows does not have to be considered at all. Furthermore, the derivation of the Beta value of the customer segments is treated only very superficially, so that the practical application of the models discussed above seems rather difficult. Although the basic CAPM has been advanced in the last decades (e.g. Hansen and Richard 1987; Merton 1973; Söderlind 2006), for instance, to account for intertemporal decisions and conditioning information (in the context of customer valuation such approaches can be used to consider managerial flexibility), the discussion shows that the underlying (basic) assumptions are associated with some serious drawbacks.

The following section presents a model for customer portfolio management, which is based on the portfolio selection theory of Markowitz (1952; 1959). It will be shown that some of the previously discussed disadvantages of the CAPM in the context of CRM can be avoided by applying the portfolio selection theory:

(ad 1) For portfolio selection theory, it is not necessary to assume homogenous expectations and define the market portfolio (or the Beta value) in order to determine the risk-return-profile of customer segments. In fact, a company can estimate the cash in- and outflows of each customer segment based on its own individual expectations and its current customer base. This may be used for the evaluation of adding or subtracting a customer segment to or from the firms' customer portfolio as well as for determining a new customer portfolio (shown in the section *Composition of a new customer portfolio*). Furthermore, it is necessary to consider, for instance, fixed costs (e.g. acquisition costs) if a new customer segment may be added to the portfolio. For that reason we adapted the Markowitz algorithm by two novel heuristics within this paper.

(ad 2) Instead of considering only the systematic risks of a customer segment, the portfolio selection theory takes into account all risks. This is a major advantage since the influence of environmental effects and especially macroeconomic changes (see Hogan et al. 2002) are represented by unsystematic risks. E.g., (linear) dependencies between changes of the incomes of different customer segments (caused by a recession and thus a reduced size of wallet) can be represented mostly by correlations between customer segments. Since no appropriate approaches in the context of customer segment valuation exist to manage unsystematic risks, we focus on these important risks in order to optimize new and existing customer portfolios.

(ad 3) By means of the portfolio selection theory, effects of risk diversification through imperfect positive correlation between customer segments can be analyzed (CAPM ignores the fact – as mentioned above – that even with imperfect correlation one can realize diversification effects). Thus marketers may profit from risk diversification through selection of the optimal customer portfolio based on the set of efficient portfolios (customer portfolios which are not dominated by at least one other portfolio). The choice of the optimal portfolio depends on the individual risk aversion, which can be derived from the preference relation of the decision maker.

Another advantage of the model which is presented in the following is that it supports the marketer's abilities to differentially deploy investments to each customer segment. Two types of investments can be distinguished. Firstly, investments that may be assigned to a specific customer segment, although still independent of the number of customers, are treated as direct fixed costs (e.g. development of an information system, which is used for a specific customer segment). However, those investments that may be assigned to customers of a specific customer segment and are therefore dependent on the number of customers (e.g. costs of direct customer contact or addressing new customers), are referred to as direct variable costs. Based on this distinction it is possible to analyze which investments lead to which benefit of the optimal customer portfolio. Furthermore, in the presented model, market entry and exit barriers may be considered by minimum and maximum restrictions of the size of customer segments. Thus, the model considers the fact that due to entry barriers some segments cannot be acquired to the desired extent and other segments cannot be scaled down due to exit barriers respectively.

Summing up, it will be shown that the application of the portfolio selection theory in customer relationship valuation allows for clear implications on the composition of the customer portfolio, according to the expected CLV of the different customer segments and the risk associated with it. Furthermore, we will derive the monetary value per capita of the customer base. The aggregation of the customer value per capita to the value of the customer base as a whole is important to enhance comparability of shareholder value and customer value. However, the focus of this paper is to develop a decision model that gives clear indications for the composition of the customer base on the basis of the principles of shareholder value.

CUSTOMER PORTFOLIO VALUATION MODEL

Assumptions

The application of portfolio selection theory and the derivation of a suitable valuation method require a few assumptions about the distribution of cash flows and the behavior of decision makers. These are briefly presented in the following.

(A1) *The number of customer segments $i = 1,\ldots,n$, with maximum market size $M_i > 0$, in the existing customer portfolio of a company is n at time $t = 0$. These are assumed fixed over the whole planning horizon $t = 1,\ldots,T$. The customer portfolio of all segments together consists of $N \in \mathbb{N}$ customers at time $t = 0$. The portfolio shares w_i of the segments, given by the ratio of the number of customers in segment i and the total number N of customers in the portfolio, are the decision variables of the portfolio optimization in $t = 0$ for the whole planning horizon. The portfolio shares are at least zero and sum up to one, i.e.*

(3.1) $$\sum_{i=1}^{n} w_i = 1, \qquad w_i \geq 0 \quad \forall i \in \{1,\ldots,n\}.$$

For all $t \in \{1,\ldots T\}$ from t-1 to t, N changes by the given growth rate[2] g, with $g \in (-1;\infty)$. The parameters N, Mi and g are assumed feasible, i.e. on the global level

(3.2) $$N \leq \sum_{i=1}^{n} M_i \quad for \quad g \in (-1;0],$$

[2] The analyses can easily be extended to the case of segment-specific growth rates g_i, with i = *1,…,n*, if the per capita view, normalized to the number of customers at time *t* = 0, is still kept. Thus we can incorporate differently growing and shrinking segments into the analyses. In this case we have to substitute assumption *(A1)* by *(A1')* of Appendix 1 and change some of the following inequalities and equations as is shown in Appendix 1.

$$N \cdot (1+g)^T \leq \sum_{i=1}^{n} M_i \quad for \quad g \in (0;\infty).$$

From assumption (A1) it follows that on the customer segment level, we receive the upper bounds $\overline{w_i}$ for the portfolio shares

(3.3)
$$\overline{w_i} = \frac{M_i}{N} \quad for \quad g \in (-1;0],$$
$$\overline{w_i} = \frac{M_i}{N \cdot (1+g)^T} \quad for \quad g \in (0;\infty).$$

From the inequalities in (3.2) and the equations in (3.3) it follows for the upper bounds $\overline{w_i}$ that their sum is greater or equal to one:

(3.4)
$$\sum_{i=1}^{n} \overline{w_i} \geq 1 .$$

Therefore, we may note that the feasible intervals for the portfolio shares w_i of the customer segments are $w_i \in [0;\min\{\overline{w_i};1\}]$ for all $i \in \{1,...,n\}$.

Each segment i yields the cash inflow $CF_{i,t}^{in}$, which is the average periodic revenue per capita at time t, with $t \in \{0,...T\}$, as well as the average cash outflow per capita $CF_{i,t}^{out}$. The latter is the total of direct variable costs, which depend on the number of customers in the segment. These costs result from acquisition, service and advisory as well as transaction costs. The calculation of the segment-specific cash outflow does not, however, include those costs that indeed can be assigned to a certain customer segment, but do not depend on the number of customers. Hence, these direct periodical fixed costs $F_{i,t}$ of segment i at time t, with $t \in \{0,...T\}$ are independent of the number of customers in segment i and arise primarily due to contractual commitments before time $t = 0$.[3] These contain, for instance, costs for rented buildings, leasing costs or license fees for information systems. Direct fixed costs may amount to an important size, but if the respective segment $i \in \{1,...,n\}$ (with $w_i \neq 0$) is part of the existing customer portfolio, its fixed costs have to be treated as sunk costs, and therefore have no impact on the portfolio optimization. However, their NPV per capita in the respective segment, which is normalized to the number of customers in the segment at time $t = 0$ - irrespective of the growth rate g -, i.e.

(3.5)
$$NPV(\hat{F}_i) = \frac{1}{w_i \cdot N} \sum_{t=0}^{T} \frac{F_{i,t}}{(1+r_f)^t} ,$$

where r_f denotes the risk-free rate, has to be taken into account should a new portfolio be arranged, e.g. an existing portfolio should be enlarged by a new customer segment.

Indirect periodical fixed costs IC_t, like management costs, overhead and administration costs, which are independent of the number of customers in the customer portfolio as well, are difficult to allocate to specific customer segments. Nevertheless, for creating shareholder value, their NPV per capita, also normalized to the number of customers at time $t = 0$, i.e.

[3] Direct fixed costs, which arise at time $t \in \{0, ..., T\}$ and are not a consequence of contractual commitments before $t = 0$, will be neglected at first. Later, it will be shown that these costs, which are relevant for the portfolio decision even in the case of an existing customer portfolio, may be integrated into the model as well.

(3.6) $$NPV(\hat{IC}) = \frac{1}{N}\sum_{t=0}^{T}\frac{IC_t}{\left(1+r_f\right)^t},$$

should at least be covered by the value per capita of the customer portfolio.

(A2) *For every customer segment i, with i ∈ {1,...,n}, the average per capita net cash flow Q_i is given by $Q_i = \left(\tilde{q}_{0,i}, \tilde{q}_{1,i}, \ldots, \tilde{q}_{T,i}\right)$. The components $\tilde{q}_{t,i}$ are the average net cash flows per customer in customer segment i and represent the delta of cash in and outflows at time t ∈ {0,...T}:*

(3.7) $$\tilde{q}_{t,i} = CF_{t,i}^{in} - CF_{t,i}^{out}.$$

$\tilde{q}_{t,i}$ are assumed to be independent and identically distributed random variables, which are given at the decision time t = 0, as well as the direct fixed costs $F_{i,t}$ of segment i and indirect fixed costs IC_t. The average per capita Customer Lifetime Value CLV_i of segment i, which is also normalized to the number of customers in segment i at t = 0, is given by the expected NPV of Q_i, in consideration of the periodical growth rate:

(3.8) $$\mu_i = E(CLV_i) = \sum_{t=0}^{T}\left(\frac{E(\tilde{q}_{t,i})}{\left(1+r_f\right)^t}\right)(1+g)^t.$$

For the following model, we define the expected return per capita μ_i of customer segment i as $E(CLV_i)$ at time $t = 0$, as is done in equation (3.8). Hillier and Heebink (1965) showed that if the net cash flows are supposed to be independent and identically distributed random variables, it may be concluded that the expected return per capita μ_i is asymptotically normally distributed.

On the basis of assumptions (A1) and (A2), the expected NPV per capita of the customer portfolio $E(CLV_{PF})$, shortly denoted as μ_{PF}, may be calculated as the sum of the weighted NPV of all segments' μ_i:

(3.9) $$\mu_{PF} = E(CLV_{PF}) = \sum_{i=1}^{n} w_i \cdot E(CLV_i) = \sum_{i=1}^{n} w_i \cdot \mu_i.$$

The decision maker has to choose an appropriate customer portfolio now, according to his risk preference. This is, a risk neutral decision maker considers only the expected portfolio return μ_{PF} in his decision and therefore aims to maximize the shares of the customer segments with the highest μ_i in the portfolio. A risk averse decision maker, however, takes the risk of the portfolio return into account as well. This is summarized in the principle of Bernoulli, which reasons that decision makers aim to maximize the expected utility of an alternative rather than its expected return.

(A3) *It is assumed that the risk averse decision maker aims to maximize the utility per capita of the portfolio alternatives. The risk of the expected return per capita of customer segment i is quantified by the standard deviation $\sigma_i = \sqrt{Var(CLV_i)}$. The risk σ_{PF} of the expected portfolio return per capita involves the standard deviation σ_i of the portfolio segments as well as their covariance Cov_{ij}, i.e. $\sigma_{PF} = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n} w_i \sigma_i w_j \sigma_j \rho_{ij}}$. The correlation coefficients $\rho_{i,j}$, which are supposed to be smaller than 1, i.e. correlation is imperfect, are given in time period t = 0 and are constant over the planning horizon. For all possible values x assumed by the random variable CLV_{PF}, their utility is given by*

(3.10) $$u(x) = 1 - e^{-ax}.$$

The parameter a denotes the Arrow-Pratt measure that indicates the individual level of risk aversion.

A rational preference relation that meets assumptions (A2) and (A3), i.e. in case of normally distributed random variables, the utility function given in (3.10) and compatibility with the Bernoulli-Principle, is given by the following equation:

$$\Phi_u(\mu_{PF},\sigma_{PF}) = \mu_{PF} - \frac{a}{2}\sigma_{PF}^2 = U_{PF} \quad \rightarrow \quad Max! \tag{3.11}$$

The parameters μ_{PF} and σ_{PF} both depend on the portfolio shares w_i of the different customer segments i, which have to be chosen so that $\Phi_u(\mu_{PF},\sigma_{PF})$ is maximized. Again, the parameter a represents the Arrow-Pratt measure. In the context of relationship valuation, $a/2$ is defined as a monetary factor that reflects the price per unit of risk, i.e. the reward asked by a risk averse decision maker for carrying the risk σ_{PF} (Huther 2003, p. 155). Since the portfolio shares w_i of the different customer segments sum up to one, the expected portfolio utility U_{PF} is a monetary per capita amount.

Valuation of an existing Customer Portfolio

In this section, we will optimize an existing customer portfolio on the basis of the portfolio selection theory, wherein the customer segments are given, but not their optimal portfolio shares w_i (Markowitz 1952; 1959). We will firstly derive μ_{PF} and σ_{PF} of all efficient portfolio alternatives and secondly determine the optimal portfolio. The analysis considers the expected return per capita μ_i of all customer segments as well as their variance σ_i^2 and covariance Cov_{ij}. The fixed costs $F_{i,t}$ of segment i are not taken into account in the optimization for the reasons explained above. The comparison of the existing customer portfolio and the optimal portfolio shows which customer segments have to be enlarged or rather diminished in order to increase shareholder value.

Starting point of the portfolio selection theory is a risk averse decision maker, who chooses between efficient portfolios, i.e. portfolios with higher expected return accompanied by higher variance and portfolios with lower expected return and variance. Furthermore, he will only select a portfolio PF, which is a feasible portfolio, i.e. all portfolio weights are part of the feasible interval of $w_i \in [0; \min\{\overline{w_i};1\}]$ and the portfolio shares sum up to one. However, it may be reasonable to include minimum restrictions for the portfolio shares of the different customer segments as well. For instance, if a customer segment is strategically important, since customers of this segment act as reference clients (social effects) on the market or the segment is needed to enter a market. Thus, we will consider lower bounds $\underline{w_i} \in \left(0; \min\left\{1; \overline{w_i}\right\}\right)$ for the portfolio shares in the analysis, too, so that the feasible interval for the portfolio shares is given by $w_i \in [\underline{w_i}; \min\{1; \overline{w_i}\}]$.

To derive the set of efficient portfolios, we minimize the portfolio variance at every level of portfolio return. If the returns of the different segments are imperfectly correlated, the overall portfolio risk is smaller than the sum of the individual variances of the customer segments. Therefore, the more assets or customer segments are in the portfolio, the better portfolio risk can be diversified (Markowitz 1959). However, this is only true if the segments are positive imperfectly correlated. In the case of negative correlation the direct opposite takes place. Negative correlations may arise, if the great many of customer segments within the portfolio lead – for instance – to a bad maintaining and enhancement of customer relationship (e.g. overwork of sales). I.e. the "targeting" on specific customer segments changes for the worse and a larger portfolio with more segments leads to an significant increase of portfolio risks (furthermore, this may also lead to a decrease of the CLV of the customer segments resulted though, for instance, bad and not individualized customer services). Such effects have to compare with diversification effects resulting from imperfect, positive correlations, which already exist in most cases (cf. Ryals 2001).

The selection of the optimal portfolio out of the set of efficient ones depends on the individual risk aversion, which is represented by the indifference curve in a (μ_{PF}, σ_{PF}^2)-diagram. It can be derived from the preference relation given in equation (3.11). The point of tangency of the indifference curve and the efficient frontier represents the locus of the optimal portfolio at the given risk preference. If it is optimal to reduce the customer portfolio by segment *i*, its portfolio weight will consequently be $w_i = 0$ in the point of tangency. With the expected return and variance of the optimal portfolio, its utility can be calculated by equation (3.11).

Finally, the utility per capita of the optimal portfolio has to cover the average NPV of direct and indirect fixed costs per capita to create value for the company. Although these costs are sunk costs in the case of an existing customer portfolio, the company creates value only if the portfolio utility exceeds all fixed costs. Therefore, we have to weight the direct fixed costs per capita of the segments *i* of equation (3.5) with their respective portfolio share w_i.[4]

The Markowitz algorithm thus allows the determination of the average utility per capita of a customer portfolio with a given number of customer segments. Furthermore, we derive exact portfolio weights with respect to an individual utility function and therefore management can decide whether the portfolio share of customer segment *i* should be enlarged or diminished. Which benefits can finally be drawn from the application of the model?

In most cases an already existing customer portfolio of a company resulted from uncoordinated decisions made in the past, i.e. from sporadic, uncoordinated acquisition efforts, coincidental acquisitions, as well as from self-selection by consumers who base their individual decisions on available offers and options. In practice, the necessity of a strategic customer management, including the structure of a company's customer portfolio in terms of the above mentioned risk factors is often underestimated. On the one hand, the model can be useful to make these risks more transparent and quantifiable (e.g. cluster risks due to strongly correlated segments). On the other hand, acquisition efforts can be used to reduce such (cluster) risks by means of imperfect correlation of the expected cash flows of different customer segments. If such cluster risks can be avoided, a risk averse decider would usually weight the segment with the highest stand-alone utility (only cash flows and standard deviation) most highly.

By analyzing a customer portfolio in terms of its risk return profile, dependencies on future investments in acquisition, services or advisory of customers become more transparent. Therefore, it can be advantageous to invest in services of a customer segment *a*, which has a smaller expected average CLV per capita than another segment *b*, if the correlation of segment *a* to the portfolio is lower than the one of segment *b*. Risk diversification is the reason for this effect. This does not only apply to single investments but also to potential, different sets of investments. In a similar way, large companies try to diversify market risks by their different business divisions for generating constantly high revenues, independent from economic cycles. This applies not only for customer portfolios of small and medium sized enterprises but also for large-scale enterprises.

While minimum and maximum restrictions in the model can be defined, both existing market entry barriers and exit barriers can be considered. In practice, companies often cannot accomplish an acquisition of the focused customers of a segment to the optimal extent. Regional markets, for instance, in which they were not represented until now cannot be entered due to existing entry barriers. The same applies to market exit barriers, i.e. an enterprise wants to reduce the number of customers of an unprofitable segment in the long run. For both cases, minimum and maximum restrictions can be determined for the particular

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[4] With the weighting of direct fixed costs per capita of segment *i*, the portfolio share w_i in equation (3.5) is cancelled out. Hence, the NPV of direct fixed costs can be divided by the total number of customers *N* at time $t = 0$ and therefore is a constant amount – irrespective of the segment's share w_i. For reasons of better interpretation and analysis, however, the fixed costs of segment *i* are in the first step normalized to the number of customers in the respective segment, who actually cause the fixed costs.

segments. Thereby, the best possible composition of the customer portfolio can be calculated considering risk-/return-aspects.

A further issue addresses opportunity costs. If the model proposes the reduction of the portfolio weight of an existing segment, then opportunity costs of not making sales to the customers of this segment will seem to be rather high. This may especially be the case when these opportunity costs are compared to e.g. the low costs of mailing sales offers to these customers. Two aspects should be considered: First of all the low costs of such a customer contact are already considered in the respective cost parameters of the segment (direct fixed costs by the parameter $F_{i,t}$ and direct variable costs by the cash outflow variable $CF_{i,t}^{out}$). It can be concluded that the optimal customer portfolio was already calculated based on this data. Furthermore, the money invested in the above mentioned customer contact is bounded (given a realistically limited budget which is also expressed by the limited range of the customer base) and is thus missing somewhere else. That is, in this case opportunity costs e.g. for another segment could arise, too. The model compares both kinds of opportunity costs. Therefore, the resulting solution takes into account that the next dollar should be invested in the new segment instead of the existing segment to optimize the risk-/return-profile. Taking into account those opportunity costs, the lost profit would be larger – assuming the cash flows can be correctly assigned to a certain customer segment – if the enterprise does not invest in the new segment.

Composition of a new Customer Portfolio

Suppose the situation of a newly established firm, which has not acquired any customers yet. According to financial resources and the working capacity of the company, the management of the company is able to determine a number of customers that can be served. However, it is still unclear, which customer segments should be considered, and how they should be weighted in the portfolio. For the derivation of the new portfolio, we have to slightly modify assumption (A1) substituting the upper part of (A1) by the following (A1').

(A1') *The number of potential customer segments $i = 1,\ldots, n$ on the market is n at time $t = 0$, with maximum market size $M_i > 0$, which is fixed for the planning horizon. The number of segments in the customer portfolio and the portfolio shares w_i of these segments are now the decision variables of the portfolio optimization in $t = 0$, in consideration of the minimum restrictions $\underline{w}_i$ and maximum restrictions $\overline{w}_i$.*

Since all customer segments are new in the portfolio, their fixed costs $F_{i,t}$ must not be treated as sunk costs and now have to be considered in the analysis. Fixed costs are independent of the portfolio weights w_i, and therefore they are not taken into account in the optimization algorithm that was used in the previous section. In order to obtain the optimal solution for a new customer portfolio, considering fixed costs, a complete enumeration of portfolio combinations requires, for n potential target groups or customer segments, the calculation of the utility of $(2^n$-1) portfolios. In the case of, e.g. 20 customer segments, the utility of 1,048,575 portfolios has to be derived. Since this procedure is enormously time and thereby cost consuming, this section aims to develop a heuristic method that requires less computing time to find a solution. Moreover, in practice it might be of higher strategic importance as to whether an existing customer base should be reduced or enlarged incrementally by taking a customer segment out of or into the portfolio. Therefore, the presented model allows for an incremental valuation of the customer segments.

The model consists of two algorithms, henceforth referred to as "subtract"-approach and "add"-approach, which may be applied for the decision. Since both algorithms are heuristics, their results do not necessarily have to be the optimal solutions. However, if both procedures derive the same portfolio, we might take this as an indication that we have possibly derived the optimal solution. In the following, we will refer to this portfolio (which is the result of both procedures) as "approximate solution" to the optimization problem. In general, however, the two algorithms do not necessarily lead to the same result. In this case, the decision maker will choose the portfolio with the higher utility.

Before starting with the "subtract"-approach, we will derive the portfolio shares w_i of all n potential customer segments identified on the market by constructing the efficient frontier. Based on this, we will calculate the point of tangency of the efficient frontier and the indifference curve (in analogy to the procedure described in the previous section). The resulting portfolio will henceforth be denoted as "pre-optimal portfolio". Since fixed costs drop in an optimization with respect to the portfolio weights w_i, they are set to zero in the first step. This portfolio represents the starting point of the "subtract"-approach, which will be described in the next section.

The "Subtract"-Approach

As the term indicates, the "subtract"-approach considers in a first step all potential customer segments in the portfolio as it was described in the previous section (for details see Appendix 2). Then, one by one the segments that are not subject to a minimum restriction and that destroy utility are subtracted. This is true for those segments, where the decremental reduction of portfolio utility is lower than their fixed costs: in general, reducing the portfolio by one customer segment not only leads to decreasing portfolio utility, because of the effects of risk diversification, but also to decreasing per capita fixed costs in the remaining portfolio. The algorithm finally stops if no more customer segments can be excluded from the portfolio that are not subject to minimum restrictions and destroy utility. However, the customer portfolio should be realized only if the portfolio utility exceeds the fixed costs that arise with the business activity of the company, i.e. the average NPV of indirect fixed costs per capita and the weighted sum of direct fixed costs per capita of the segments in the portfolio. If all fixed costs are covered by the utility of the portfolio, the "subtract"-approach derived a solution to the optimization problem that determines the portfolio weights of the segments in the resulting portfolio and the utility minus indirect and direct fixed costs per capita of the resulting portfolio.

The "Add"-Approach"

The "add"-approach, on the other hand, starts with all customer segments that are subject to minimum restrictions in the portfolio (for details see Appendix 3). It subsequently enlarges the portfolio by step by step adding further segments to the portfolio that contribute to an increased portfolio utility despite of the fixed costs associated with them: in general, an additional customer segment in the portfolio leads to a higher portfolio utility, because of the effects of risk diversification as was noted before. On the other hand, the per capita fixed costs of the portfolio segments rise as well by including another segment. Both effects have to be charged against each other. If no more customer segment can be included in the portfolio that creates utility, we check again if the portfolio utility exceeds all fixed costs as was done in the "subtract"-approach. If this is true, the "add"-approach produces similar results as the "subtract"-approach: the set of the segments in the resulting portfolio with the respective portfolio weights, as well as the portfolio's utility minus indirect and direct fixed costs per capita.

After both algorithms are completed, results have to be compared. If they are identical, the common result is regarded as the "approximate solution" to the optimization problem. If both algorithms produce different portfolios, the decision maker, who aims to maximize utility, chooses the resulting portfolio with the highest utility reduced by direct and indirect fixed costs per capita.

Reduction or Enlargement of the existing Customer Portfolio by the Exclusion or Inclusion of Customer Segments

In reality, the construction of a new customer portfolio that does not contain any customers at time $t = 0$ will be rare. In fact, the decision as to whether the diversification of an existing customer base should be reduced or enlarged by taking customer segments out of or into the portfolio will normally be even more relevant. With the help of the previously described "subtract"- and "add"-approach, we may now include those direct fixed costs, which arise at time $t \in \{0, ..., T\}$ and are not a consequence of contractual commitments before $t = 0$ (cf. footnote 3).

First of all, we will consider the case of reducing the existing customer portfolio. Since the weighted NPV of those direct fixed costs per capita $w_i \cdot NPV(\hat{F}_i)$ of segment *i*, which are relevant for the portfolio decision, can be saved by excluding segment *i*, we have to consider segment i for the derivation of the optimal portfolio. Applying the "subtract"-approach, all segments within the portfolio (except for the segments being subject to minimum constraints) are one at a time taken out of the existing customer portfolio. For every new portfolio, the efficient frontier as well as the point of tangency with the indifference curve is calculated (Markowitz algorithm). We add the saved costs of the excluded segment *i* to the resulting portfolio utility, which will in general be smaller than the utility of the portfolio before the exclusion of the segment. In doing so, we may exclude in each iteration of the "subtract"-approach the economically worst customer segment from the existing portfolio.

Secondly, we examine the incremental enlargement of the existing portfolio by step by step taking further customer segments into the portfolio. The inclusion of a new customer segment is rational if and only if the incremental increase of portfolio utility per capita is higher than the fixed costs involved with the new segment. Thus, we have to consider the weighted fixed costs per capita of the new segment, as well as the decision-relevant weighted fixed costs of the segments that are already part of the portfolio. To select the economically best customer segment, we may apply the "add"-approach. This algorithm now starts with the existing customer portfolio (Markowitz-solution) plus those segments that are not part of the existing portfolio but are subject to minimum constraints. The algorithm extends the existing customer portfolio step by step by taking those new segments into the portfolio that contribute to an increased portfolio utility, even if the relevant weighted fixed costs per capita are subtracted.

Thirdly, we may combine the approaches just discussed by again applying the "subtract"- and "add"-approach to derive the "approximate solution" to the optimization problem. The starting portfolio for both algorithms is the (weight-optimized) existing portfolio including segments that are subject to a minimum constraint. At first, we apply the "subtract"-approach and take one customer segment at a time out of the starting portfolio until the delta between the new portfolio utility and the portfolio utility of the previous iteration is smaller than the weighted NPV of the fixed costs per capita of the just excluded segment *i*. The resulting portfolio constitutes the starting portfolio for the following "add"-approach. Here, we add the segments that are not part of the portfolio yet one by one to the portfolio until the delta between the new portfolio utility and the portfolio utility of the previous iteration is larger than the weighted NPV of the fixed costs per capita of the just excluded segment *i*. The "subtract"- and "add"-approach are carried out repeatedly until the portfolio utility cannot be increased anymore. The same procedure is applied, starting with the "add"-approach. If the results of both combinations of the two algorithms are identical, we apparently derived the "approximate solution" to the optimization problem. If results differ, we take the portfolio with the higher utility.

In contrast to the algorithm of Markowitz, the two heuristics can be used to analyze the effects of an incremental enlargement of an existing customer portfolio, which requires particular investments (primarily for the market entry). These investments do not depend on the number of customers in the segment, which means they can be regarded as fixed costs. Thus, for example, market entry barriers - resulting from the (initial) development of a brand or of specific products for a new segment - can be considered. Such barriers are not only represented in maximum restrictions but also in new, decision-relevant investments (direct fixed costs $F_{i,t}$) for the customer segment. Similarly, market exit barriers - caused by the exclusion of a long-term unprofitable customer segment and the necessary initial "investments" for it - are covered by the heuristics.

APPLICATION IN THE FINANCIAL SERVICES INDUSTRY

The customer portfolio valuation model developed in the previous part will now be illustrated by an example of the financial services industry, where the model was applied. For the sake of anonymity, the internal data of the company are substituted by slightly changed amounts.

Many firms in the financial services industry identified students and young academics as a potentially highly profitable target group (Ryals 2002). Although these customer relationships may be unprofitable in the short run, companies assume that they will prove to be valuable over their lifetimes because of an above-average income in relation to other customers and better perspectives on the labor market.

The financial services company concerned aims to optimize its customer portfolio with respect to the profitability and risk of nine different customer segments that could be identified as being relevant within the target group of academics: architects, lawyers, physicians, economists (including MBA's), natural scientists, computer scientists together with mathematicians, pharmacists, engineers and arts scholars.

In a first scenario, we assume that the company's present customer base is composed of three of the named customer segments: lawyers, physicians and economists, which gain the following portfolio shares: lawyers 60%, physicians 10% and economists 30%.

We verify by means of the portfolio selection theory, whether the present customer base is optimal, and in case it is not, which portfolio shares of the existing customer segments have to be enlarged or diminished.

In a second scenario, we analyze if the portfolio utility of the existing customer portfolio can be increased by adding further segments or taking segments out of the portfolio. Therefore we apply the "subtract"- and "add"-approach to derive an "approximate solution" for the optimal customer portfolio.

Estimation of the Model Parameters

Before we can analyze the customer portfolio, all model parameters of the different customer segments have to be estimated.

The estimation of an expected CLV per capita of every customer segment was based on two starting points. First, the financial services company analyzed the data stored for a number of customers of a segment on an individual level (this could not be done for all customers since the data were stored in many different information systems, i.e. the manual integration of the data was difficult and highly cost intensive). The aim was to determine product sales and cash flows of previous periods. Based on these cash flows in different time periods, it was possible to generate the cash flow time line for each customer. By means of clustering and time series analysis, one or more typical cash flow time lines for every customer segment was deduced. For such problems algorithms can be employed (see Agrawal et al. 1995; Mani et al. 1999) that identify differences and similarities of cash flow time lines by means of operators like scaling (removal of different levels and margins of deviation) or elimination (elimination of outliers und singular event). Given the assumption that the cash flow time lines, generated based on historical data, are typical for a customer segment, an expected CLV per capita can be estimated. However, it is widely agreed that performance in the past does not reflect future cash flows properly. Indeed, the latter may deviate substantially due to external factors (second starting point for the calculation of an expected CLV per capita of every customer segment). In the financial services industry, the income of the customer is the factor with the strongest impact on business activity (Fed 2006; Spiegel 2005). This is, the higher the income of the customer, the more he is able to invest in financial products. Therefore, it is reasonable to assume a strong correlation between real income and cash flows of the financial services company. In consequence, we can derive the impacts on the average cash flow per capita for every customer segment in relation to the real income per age in every customer segment over the planning horizon of T = 10 years. Reproducing the real income development over the customers' lifetimes, we used income data of the German labor market of the year 2004, readily available from PersonalMarkt (PersonalMarkt 2005). We assume that the real income level of, for instance, a 30 year old customer in 2004 equals (20 years later) the real income level of a customer, who is 50 years old in 2004. I.e. we suppose similar real income development over the customers' lifetimes. In this context, the studies by (Fed 2006) and (Spiegel 2005) point out how much a customer is investing in financial products on average (depending on his age, his gross income and the annual rate of change of the gross income). On this basis we can estimate the impact of external factors like the development of incomes on the expected cash flows and their standard deviation for each customer segment considering the average share of wallet of the financial services provider.

In the resulting cash flows, we still have to consider the growth rate $g \in (-1,\infty)$, which reflects the variation of the number of customers in the customer base. In the present example, we assume a (fictitious) increase of the customer base of 10% per year over the planning horizon given. This is feasible for the midsize financial services company considered in the case study. Finally, the resulting cash flows per customer segment have to be discounted and summed up to the expected CLV per capita, which are shown in Table 1.

TABLE 1
Income, Relative Standard Deviation of Income, Expected CLV[5] and Absolute Standard Deviation of the CLV per Customer Segment

Customer segment	*Gross income per year*	*Standard deviation of gross income relative to average gross income*	*Expected CLV per customer (in 1,000 euros)*	*Absolute standard deviation of the CLV (in 1,000)*
Architects	45,969	34.5%	1.769	0.610
Lawyers	75,393	44.9%	2.592	1.163
Physicians	72,025	45.6%	3.445	1.572
Economists	74,459	49.1%	2.808	1.380
Natural scientists	62,996	42.5%	1.739	0.739
Computer scientists/ Mathematicians	65,092	31.5%	2.256	0.711
Pharmacists	70,632	42.6%	2.762	1.177
Engineers	63,411	40.1%	2.665	1.069
Arts scholars	42,135	42.8%	1.634	0.699

In order to estimate the deviation, i.e. the risk of the expected CLV, some authors recommend the usage of risk scorecards that define how strongly particular factors, often identified by experts of the industry, affect cash flows (Ryals 2001; Dhar and Glazer 2003). However, this approach seems to be hardly convenient, since the qualitative assessment of experts still has to be transformed into some quantitative measure such as the standard deviation. Therefore, we will use the average relative standard deviation of the segment-specific income as a proxy for the standard deviation of revenues, since, as stated above, the income is the factor with the strongest impact on cash flows.

[5] Expected CLV per capita over a planning horizon of $T = 10$ years

The most important characteristics of this procedure are: On the one hand, there is a strong dependency between the income level of a customer segment and its demand for financial products, i.e., the higher the income of the customer, the more he needs and is able to invest in financial products. This in turn creates the cash inflows of the financial services provider. Consequently – so the underlying assumption – correlated changes of incomes of two segments result in correlated investments in financial products. Therefore, we use the correlations between incomes to estimate the correlations between cash inflows of two segments. On the other hand, these correlations are not based on the aggregated former cash inflows of a customer segment because we consciously wanted to use documented demand for financial products that is company independent. The said demand is independent from former changes of products etc. of a financial services provider. Consequently, the demand for financial products is more adequate to estimate correlations and risks, which are resulting from macroeconomic factors.

Hence, the procedure for the determination of the standard deviation and correlation is split into two steps. Firstly, we identified the average incomes of the customer segments (in the last ten years). Secondly, we calculated the individual standard deviation based on the incomes of one segment. Subsequently, we estimated the concrete correlations between two segments based on their incomes for each year. This approach is advantageous particularly because it is a rather objective estimation method of risk. In contrast, using a risk scorecard supports the subjective view of management and experts, who may overvalue less important risk factors and neglect crucial ones (Hopkinson and Lum 2001).

Table 1 shows the average income per capita of every customer segment over all age groups and its relative standard deviation (PersonalMarkt 2005). The relative standard deviation of gross income, given in the third column of Table 1, multiplied with the fictitious expected CLV per customer segment allows the estimation of the standard deviation of the CLV to be given in absolute terms as in the fifth column in Table 1.

Examining the CLV of the different segments, physicians seem to be the most profitable customers. On the other hand, the standard deviation of their CLV is very high, too. If management tends to favor less uncertain cash flows, they will probably prefer a segment with a lower, but less risky CLV, like architects for instance. Thus, if the price of risk can be determined and with it the parameter a of risk aversion (see equation (3.11)), the utility per capita of every customer segment according to its CLV and individual risk can be calculated.

However, we argued in section two that besides segment-specific CLV and risk the correlation between the segments also has to be considered. As outlined above, the deviation of cash flows highly depends on the real income development. Therefore, correlation between cash flows can be assessed by analyzing the impact of exogenous factors on the segment-specific real incomes of the past. Correlation measures the extent to which the incomes of two customer segments are affected by the exogenous factors in the same way. Again, this approach seems to be preferable compared to purely qualitative approach based on expert interviews, since it allows for the quantitative assessment of the correlation coefficients. The correlation coefficients, which were used in our example, are shown in Table 2.

TABLE 1
Correlation Coefficients between the CLV of all Customer Segments

Correlation coefficients	Architects	Lawyers	Physicians	Economists	Natural sci.	Comp. scientists/ Math.	Pharmacists	Engineers
Lawyers	0.5							
Physicians	0.4	0.5						
Economists	0.5	0.5	0.3					
Natural sci.	0.6	0.5	0.6	0.4				
Comp.sci./ Math.	0.6	0.5	0.6	0.6	0.8			
Pharmacists	0.4	0.5	0.8	0.4	0.7	0.6		
Engineers	0.8	0.5	0.4	0.5	0.4	0.8	0.4	
Arts scholars	0.4	0.7	0.4	0.3	0.6	0.5	0.4	0.3

Furthermore, direct fixed costs that may differ from segment to segment have to be determined. Physicians, for example, need different financial products and services for their accident insurance or for financing a medical practice than other customers. Consequently, databases and information systems have to be adapted and consultants have to be trained to get to know the new products. The estimations of the NPV of the direct fixed costs per customer segment over the given planning horizon are presented in the second column of Table 3. According to the weight of the respective customer segment in the portfolio, their per capita amounts may be calculated.

TABLE 2
NPV of Fixed Costs, Maximum and Minimum Portfolio Weights per Customer Segment

Customer segment	*NPV of fixed costs (in 1,000 euros)*	*Maximum portfolio weights* $\overline{w}_i$	*Minimum portfolio weights* $\underline{w}_i$
Architects	35,000	36.2%	0.0%
Lawyers	30,000	53.2%	0.0%
Physicians	40,000	60.8%	30.0%
Economists	32,500	64.1%	20.0%
Natural scientists	25,000	10.2%	0.0%
Computer scientists/ Mathematicians	25,000	6.5%	0.0%
Pharmacists	35,000	26.8%	0.0%
Engineers	35,000	100.0%	0.0%
Arts scholars	25,000	23.0%	0.0%

We estimate the NPV of indirect fixed costs, containing management costs and administration costs, over the planning horizon at 300 m euros. Finally, the number N of customers in the customer base at time $t = 0$ was set to 500,000. Employment studies allow for the determination of the maximum portfolio shares $\overline{w}_i$ of the nine segments, by dividing the number of (employed) customers on the market in the respective segment by the number of customers in the customer base. Since the segments of physicians and economists are assumed to be strategically crucial, their minimum portfolio shares are set to 30% and 20%, respectively. Since the segment of lawyers provides the lowest expected CLV of the three segments that are part of the existing customer portfolio, they are not assessed as being strategically highly important. Therefore, no lower bound for their portfolio weight is incorporated. The maximum and minimum portfolio weights of the segments are shown in Table 3.

Results of the Analysis of an Existing Customer Portfolio

In this section, we aim to optimize the existing customer portfolio. We determine the price of risk at one euro per unit of risk, i.e. the parameter of risk aversion a of equation (3.11) can be set to two euros. On the basis of the above estimations and the definition of the price of risk, the efficient frontier and the optimal customer portfolio may be calculated, considering the segment of lawyers, economists and physicians. The two curves touch at a portfolio return per capita of $\boldsymbol{\mu_{PF}}$ **= 2,992 euros** and a portfolio risk of $\boldsymbol{\sigma_{PF}^2}$ **= 1,201**. The resulting portfolio utility per capita is therefore

$$U^* = 2{,}992 \text{ euros} - 1 \text{ euro} \cdot 1{,}201 = 1{,}791 \text{ euros.} \tag{4.1}$$

The optimal portfolio shares of the three customer segments are: lawyers 28%, physicians 39% and economists 33% (compared to the weights 60% (lawyers), 10% (physicians) and 30% (economists)) of the existing portfolio. The composition of the just derived portfolio shows that the existing customer portfolio of the financial services company is suboptimal. Calculating the expected portfolio return and variance of the existing portfolio, we derive a utility per capita of ***U* = 1,621 euros**. Hence, the difference between optimal and given portfolio utility amounts to 1,791 euros – 1,621 euros = 170 euros. Therefore, the optimization yields a **10.5%** improvement of the result.

In order to check whether the utility per capita of the optimal portfolio covers the average NPV of direct and indirect fixed costs per capita, we subtract the weighted sum of direct fixed costs per capita of the three segments, which amounts to 205 euros, as well as the indirect fixed costs per capita of $(300 \cdot 10^6$ euros$)$ / 500,000 = 600 euros. The result is a portfolio utility of 986 euros and thus, fixed costs are covered by far.

In the following, we aim to analyze the composition of the optimal portfolio by means of the data given above. Therefore, we will first of all have a look at the CLV per capita of the three segments: the segment with the highest expected CLV is the segment of physicians. In the optimal portfolio, it gains the largest portfolio share. The optimal portfolio, however, does not consist only of physicians, because – as outlined above – the risk associated with the segment's CLV plays a crucial role in portfolio valuation as well. The analysis of the expected CLV, the risk and therefore utility per capita of each segment, ignoring correlations < 1, reveals that it is not the segment of physicians but the segment of lawyers that provides the largest utility. Equations (4.2 a) to (4.2 c) show the utility per capita of each segment at the specified parameter of risk aversion:

(4.2 a) U_{lawyer} = 2,592 euros – 1 euro · 1,352 = 1,240 euros,

(4.2 b) $U_{physician}$ = 3,445 euros – 1 euro · 2,472 = 973 euros,

(4.2 c) $U_{economist}$ = 2,808 euros – 1 euro · 1,905 = 903 euros.

However, the segment of lawyers is still the smallest segment within the portfolio. This may be explained by the effect of risk diversification: since physicians and economists are less correlated with each other, they help to decrease portfolio risk more than lawyers and their portfolio weights thus exceed the required minimum shares.

If the portfolio segments correlate perfectly, portfolio utility per capita would be equal to ***U** = 1,053 euros** in contrast to the portfolio utility with imperfect correlation of **1,791 euros**. This example shows that imperfect correlation between the portfolio segments helps to decrease portfolio risk and thereby to increase portfolio utility, customer value and thus shareholder value.

Using the "Subtract"- and "Add"-Approach for the Reduction or Enlargement of an existing Customer Portfolio

After the derivation of the optimal portfolio weights of the existing customer portfolio, we will at first use the "add"-approach to check whether the portfolio utility of the existing customer portfolio can be increased by adding further customer segments. Therefore, we take one of the remaining six segments at a time into the portfolio and compute its utility per capita minus the fixed costs per capita of the new segment for each new portfolio. We find that including the segment of engineers yields the highest portfolio utility despite of increased fixed costs. A second iteration, however, reveals that no further segment should be included in the portfolio. Therefore, the "add"-approach yields the portfolio with the utility minus weighted fixed costs per capita of the new segment of **1,861 euros**, which is still higher than the utility of **1,791 euros** of the above optimized portfolio (Markowitz-solution without considering fixed costs).

However, if we assume that the fixed costs of the existing customer segments in the portfolio are not sunk costs, we may use the combinations of the "subtract"- and "add"-approach that were described before. We apply at first the "subtract"- and then the "add"-approach to the optimal portfolio comprising three customer segments. Since the segment of lawyers is the only segment not being subject to a minimum constraint, it is the only segment that can be excluded from the portfolio. The exclusion of this segment does not lead to an improvement and therefore by the “subtract” -approach, no segment can be taken out. Now, we apply the “add”-approach to check whether portfolio utility can be increased by adding customer segments. Therefore, we take one of the remaining segments at a time into the portfolio and calculate portfolio utility. As stated before, we may include the segment of engineers in the portfolio. A further enlargement of the portfolio does not increase portfolio utility anymore and the “add”-approach stops. Therefore, we apply again the “subtract”-approach and may now exclude the segment of lawyers. A further iteration of the “subtract”-approach does not, however, lead to a change of the portfolio; nor does the “add”-approach. The resulting portfolio shares of the four customer segments are: lawyers 10.5%, physicians 31%, economists 20% and engineers 38.5%. These shares are regarded as the “approximate solution” to the optimization problem. As mentioned above, this heuristic approach does not necessarily lead to an optimal solution. Nevertheless it usually works fine in practice. In the case at hand for instance a (very time consuming) complete enumeration reveals that the “approximate solution” is indeed the optimal one.

That the heuristic approach leads to a remarkable enhancement in customer portfolio management can be demonstrated by constructing a completely new optimal portfolio. Taking all nine customer segments of Table 1 into account and applying the standard Markowitz algorithm derives a portfolio utility per capita of 1,939 euros. Subtracting the weighted sum of the direct and indirect fixed costs per capita reduces the utility to **944 euros**. Applying the “subtract”- and “add”-approach, on the other hand, leads to the following portfolio shares: physicians 34.2%, economists 22% and engineers 43.8%. The portfolio utility per capita minus all fixed costs is **1,106 euros**. Therefore, the presented heuristic approach yields a **17%** improvement of the result of the already optimized Markowitz-solution.

Practical Outcomes

According to the results, the acquisition efforts of the financial services provider should be focused on the segments of physicians and engineers. However, this does not mean that customers of another segment should be signed off or interesting new customers of these segments should be rejected, but it is clear that the acquisition of physicians and engineers (e.g. in acquisition campaigns) should obtain priority. The extension of the customer base due to acquisition efforts was expressed by the growth rate g. With a rising number of physicians and engineers, the shares of the lawyers and economists scale down in relation to the entire customer base. To that extent the different portfolio shares can be gradually adjusted towards the optimal portfolio composition, which is characterized by both higher utility and better risk diversification (because of the acquisition of physicians and engineers).

The improvement of the new optimized portfolio in comparison to the existing portfolio of the financial service provider and especially the risk reduction may clarify another aspect. Calculating the portfolio return per capita that can be realized at least with a probability of 90%, we obtain a value of just **1,203 euros** for the existing portfolio. In comparison, the new portfolio without engineers (Markowitz-solution) yields a value of **1,453 euros** (a change of **20.8%**) and for the new portfolio with engineers we finally get **1,546 euros** (a change of **28.5%**). These figures show that the risks of the existing portfolio are higher than the risks of the new portfolio, i. e. the existing portfolio is less stable against (exogenous) risks which can for example result from cyclical downturn (recession). Using the cyclical downturn in Germany in the years 1995 and 1996 as an example, we may hypothetically point out the risk impacts. Therefore, we consider the development of incomes of different customer segments in these years (cf. time series in Personalmarkt 2005)[6]. If the financial service provider had its present portfolio already in 1995 and 1996, then the decrease or stagnation of incomes would have reduced the sales of financial products and services (cash inflows of the financial service provider) much more in comparison to the new portfolios. This affects the cash inflows of the financial service provider and thus the NPV of all customer segments (but to a different extent). We can determine the difference of at least an 8.2% higher

[6] For reasons of simplification we do not change the other model parameter in this example (ceteris paribus-assumption).

portfolio return per capita for these two years by the new portfolio with engineers related to the existing portfolio. I. e. risk diversification as a result of adding a further customer segment and particularly also due to a higher weight of the segment of physicians – who are less affected by cyclical downturn in general than for example economists – would have led to actual higher cash inflows in these years. This shows that already slightly risk-averse marketers do prefer the new composed customer portfolios in comparison to the existing portfolio.

In the future, the financial services provider also intends to analyze whether a new product category - company pension schemes - should be included into the product program. However, the new products are primarily attractive for customers who are employees. Due to different shares of employees for each customer segment (e.g. the share of employees in the segment of economists is over 70% compared to approximately 20% in the segment of lawyers), the effects on both expected average CLVs and standard deviation as part of the risk differ. Customer segments which have a large share of employees improve their expected average CLV more than segments with a smaller share of employees (under the realistic assumption that the net cash flows of the new product category are positive and almost independent of cash flows of other products). Furthermore, the risk of the expected return of a customer segment - quantified by the standard deviation - also increases by the supplemental cash flows. In addition, the corresponding direct fixed costs - resulting from the new product category - have to be assigned to each segment. However, most of the fixed costs cannot be assigned to a particular customer segment in general and have, therefore, to be assigned to the portfolio (indirect fixed costs). If the product category is introduced in the future - based on sales forecasts and first sales - the customer portfolio will be analyzed and optimized. However, it is not sure whether those segments, which are the target groups for the new products, increase their portfolio shares in the case of a strongly risk averse decision maker, since the higher expected average CLVs entail higher risks, too.

As a part of the case study we analyzed whether or not it is advantageous to substitute the segment of physicians for the new segment of dentists (similar occupation group). Considering market and income analyses, the segment of the dentists promised a higher growth potential (higher expected average CLV) than the segment of the physicians. The standard deviation of the expected CLVs of both segments was similar. In contrast to this, the segment of the dentists has higher expected correlations to the other segments. Although the estimated cash outflows for the customer acquisition would not have been very high, this would have applied to the initial direct fix costs (e.g. for the development of segment-specific products, for the development of corresponding application systems and for the product training of the customer consultants). For this reason, a substitution of the existing segment of physicians was not profitable. It was also of high importance for this decision that the portfolio risks are substantially increased by the substitution (due to the higher expected correlations).

Summing up, the presented heuristic approach improved the existing portfolio to a significant level in terms of utility and supported other important decisions like to enlarge the portfolio by adding further customer segments.

CONCLUSIONS AND LIMITATIONS

The growing importance of shareholder value as a performance measure, especially for publicly traded companies, requires the quantification of all tangible and intangible assets of a company according to their growth potential and associated risk. Furthermore, it is widely agreed that customers represent the most valuable assets of a firm. To identify and select the most profitable and therefore value-creating customers, the Customer Lifetime Value (CLV) gained broad attention. The CLV aims to identify the future profitability of customers, based on the net present value concept. It does not, however, take into account the risk that the expected profitability of a customer may not be realized. Furthermore, it ignores the fact, that the risk associated with one customer or group of customers may be balanced by other, less risky customers.

This paper presented a quantitative model for the composition of a customer portfolio that considers not only the expected CLV of the different customer segments but also the risk that is associated with the estimation of uncertain future cash flows as well as the correlation between the cash flows of different customer segments. The model is based on the portfolio selection theory of Markowitz. However, the general Markowitz algorithm does not allow for the consideration of fixed costs. As it was shown, they have to be treated as sunk costs in the case of an existing customer portfolio, but they may play an important role if a new customer portfolio is composed. Therefore, the Markowitz algorithm was extended by a heuristic method consisting of two algorithms, referred to as "subtract"- and "add"-approach.

The model was applied to the case of a financial services provider. In this particular case, the segment-specific CLV's, standard deviations and correlation coefficients could be estimated with the help of the income distributions of the respective customer segments, since a financial services company's revenues obviously depend on its customers' incomes. In other industries, the revenues and thereby the model parameters, depend on factors other than the income. Therefore, the application of the model in another industry than the presented one firstly requires the identification of the relevant influencing macroeconomics factors. Companies in the food or retail sector can probably use macroeconomic factors such as consumer confidence, sentiment, spending or saving rate, which are analyzed e.g. by the Conference Board (the Index of Consumer Confidence) or by the University of Michigan Survey Research Centre (the Index of Consumer Sentiment), to estimate the consumption climate and to forecast the cash inflows of different customer segments. For this purpose it has to be explored (based on facts of the past), whether and to which extent such factors correlate with cash inflows of e.g. a retailer like amazon.com. If – similar to the financial services industry – these factors are strongly correlated, the analyzed factors cannot only be used to estimate the needs of different segments, but also to calculate standard deviations as well as correlation coefficients in the way described above. In B2B-sectors (e.g. information technology consultancy) business climate indices - like the National Association of Purchasing Managers (NAPM) index or the index of Federal Reserve Bank of Philadelphia - can probably be used in the same way for forecasting economic changes of sectors and industries. Another procedure may be to analyze the firm's own customer segments in order to find out which exogenous (given) factors mainly affect cash flows. Such factors can be of technological, political, regulatory, economical or social kind. For instance, retailers can analyze which segments of their own customer portfolio are sensitive to a general increase in prices (e.g. younger customers are less sensitive to an increase in prices than old-age customers). The aim therefore is to prepare their customer portfolio for exogenous effects like inflation and balance the risk-return-profile of their customer base.

Summing up, we can make specific statements for the financial services industry; for other industries we can only outline potential starting points at this stage.

The following general results could be learned from the analysis: it was shown that imperfect correlation between customer segments helps to diversify, i.e. to diminish, the risk of the customer portfolio. The smaller the correlation between customer segments, the more they contribute to the decrease of portfolio risk and the larger their portfolio weight should be. Therefore, even segments that seem to be unprofitable according to their CLV and individual risk may contribute to risk diversification and thus are profitable. The composition of the optimal customer portfolio depends on the risk aversion of the individual decision maker: the more risk averse he is, the more he favors customer segments with a small risk, but also small expected CLV. Besides the discussed advantages of financial portfolio selection theory in the context of CRM and the ease of use of the presented heuristic model, it shows some drawbacks that remain to be discussed and reveal directions for further research.

First of all, portfolio analysis requires *ex ante* the estimation of a large number of data: for every customer segment the expected future cash flow, the variance of expected cash flows and the covariance to every other customer segment have to be assessed. Therefore, the analysis of a portfolio consisting of n segments requires the estimation of n variances, $n \cdot (n-1)/2$ covariances and n CLV, i.e. the number of parameters that have to be estimated rises to $n \cdot (n+3)/2$. For example, if the valuation considers not only 9 customer segments (as illustrated by an example of the financial services provider), but 90 segments, the estimation of 4,185 data is required. In this paper, we tried to describe a rather simple, but effective method for the estimation of the model parameters in the financial services industry. However, the estimation of future parameters remains challenging in other industries.

Secondly, the more customer segments have to be considered, the more computing power is needed for the derivation of the efficient frontier: in the case of 90 customer segments, 90 equations have to be solved in the linear program, if no further restriction for the portfolio shares are included. Therefore, the Markowitz algorithm is time and cost consuming. The repeated calculation of the efficient frontier in the "subtract"- and "add"-approach thus affects the efficiency of the model in a negative way.

Thirdly, the model presumes that the number of customers can be determined ex ante, because only then the fixed costs per capita of the customer segments can be calculated. However, the company under consideration might not be able to determine exactly the optimal number of customers but only a probable range. In order to examine whether a different number of customers in the customer base leads to different results for the optimal portfolio, it seems inevitable to calculate the model for several scenarios. In the example presented above, the customer base may vary from approximately 211,000 to 7,850,000 customers so that we still derive the optimal portfolio. Therefore, the calculations of the model seem rather stable.

Furthermore, our model divides costs into variable costs and constant fixed costs. Some of the fixed costs, however, will increase stepwise to a higher cost level when a certain limit of customers in the segment is reached. Hence, they are no constants anymore. A more realistic modeling approach for cost effects in customer portfolio management would have to consider both constant fixed costs as well as step costs.

Finally, the model assumes that the only monetary value of a customer relationship is the cash flow that can be directly assigned to the customer. However, customers affect the profitability of the company in indirect ways, too. For instance, positive word-of-mouth between customers and prospects may help to reduce the acquisition costs of a company. Positive recommendations between customers may increase customer retention and thereby decrease portfolio risk. This implies that even non-monetary effects have to be included in the calculation of the quantifiable monetary value of a customer portfolio. The method presented can easily account for that extension, but the data requirements may be prohibitive.

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APPENDIX 1: Incorporation of segment-specific growth rates g_i

(A1') The number of customer segments $i = 1,...,n,$ with maximum market size $M_i > 0$ and the segment growth rate $g_i \in (-1;\infty),$ in the existing customer portfolio of a company is n at time $t = 0.$ These are assumed fix over the whole planning horizon $t = 1,...,T.$ The portfolio shares w_i of the segments are the decision variables of the portfolio optimization in $t = 0$ for the whole planning horizon. The portfolio shares are at least zero and sum up to one, i.e.

(Ap1.1) $$\sum_{i=1}^{n} w_i = 1, \qquad w_i \geq 0 \quad \forall i \in \{1,...,n\}.$$

The customer portfolio in all segments together consists of $N \in IN$ customers at time $t=0.$ N changes from period to period depending on the portfolio shares w_i and their growth rates g_i. The parameters N, M_i and g_i are assumed feasible, i.e. on the global level

(Ap1.2) $$\begin{aligned} &w_i N \leq M_i \quad \forall i \in \{1,...,n\}: \quad g_i \in (-1;0], \\ &w_i N(1+g_i)^T \leq M_i \quad \forall i \in \{1,...,n\}: \quad g_i \in (0;\infty) \\ &\Rightarrow \sum_{i:g_i \leq 0}^{n} w_i N + \sum_{i:g_i > 0}^{n} w_i N(1+g_i)^T \leq \sum_{i=1}^{n} M_i \ . \end{aligned}$$

From assumption *(A1')* it follows that on the customer segment level, we receive the upper bounds $\overline{w_i}$ for the portfolio shares

(Ap1.3) $$\begin{aligned} &\overline{w_i} = \frac{M_i}{N} \quad \forall i \in \{i,...,n\}: \quad g_i \in (-1;0], \\ &\overline{w_i} = \frac{M_i}{N(1+g)^T} \quad \forall i \in \{i,...,n\}: \quad g \in (0;\infty). \end{aligned}$$

Since indirect and direct fixed costs are normalized to the number of customers at time $t = 0$, and therefore are irrespective of the segment growth rate g_i, equations (3.5) and (3.6) remain unchanged.

Furthermore, equation (3.9) has to be substituted by the following equation (Ap1.4) for the incorporation of segment-specific growth rates g_i:

(Ap1.4) $$\mu_i = E(CLV_i) = \sum_{t=1}^{T} \left(\frac{CF_{t,i}^{in} - CF_{t,i}^{out}}{(1+r_f)^t} \right) (1+g_i)^t \ .$$

The remainder of the formulas in chapter *Customer Portfolio Valuation Model* remains unaffected.

APPENDIX 2: Detailed Description of the "Subtract"-Approach

Step 1: Exclusion of the worst Customer Segments

All segments not being subject to a minimum restriction are one at a time taken out of the set S of segments in the portfolio. Denote S_i as the portfolio excluding segment i and U_i the respective portfolio utility, which is the result of the re-optimization of the portfolio shares w_j, with $j \neq i$, of the segments of set S_i. Determine the delta ΔU_i between the old portfolio utility, referred to as U^* and the new portfolio utility U_i for all new portfolios. A customer segment less in the portfolio leads in general not only to a decreasing portfolio utility, because of the effects of risk diversification, but usually also to a larger number of customers in the remaining segments of set S_i, if the number of customers N is given, as was assumed in *(A1)*. Therefore, their per capita fixed costs of equation (3.5) decrease with the exclusion of segment i.[7] [8] If ΔU_i is smaller than the weighted NPV of the fixed costs per capita of the just excluded segment i in the previous iteration, i.e. if

(Ap2.1) $$\Delta U_i < w_i \cdot NPV\left(\hat{F}_i\right) \overset{(3.5)}{=} \frac{1}{N}\sum_{t=0}^{T}\frac{F_{i,t}}{\left(1+r_f\right)^t},$$

segment i destroys utility. If no such i exists, the algorithm goes to step 2.

Out of those segments destroying value, pick that segment i with minimal $\Delta U_i - w_i \cdot NPV(\hat{F}_i)$. The set S_i of segments in this portfolio is the starting point for the next iteration and therefore becomes the new set S and U^* takes the value of U_i.

Again, take all segments, which are not subject to minimum constraints, one at a time, out of the portfolio and repeat the just described procedure until the decremental reduction of portfolio utility, caused by the exclusion of a further segment, yields no more segment i satisfying inequality (Ap2.1). Then, the algorithm goes to step 2.

Step 2: Checking whether Fixed Costs are covered

As a result of step 1, no more customer segments can be excluded from the portfolio that are not subject to minimum restrictions and destroy utility. However, the customer portfolio of step 1 should be realized, and the algorithm should go to step 3, only if the portfolio utility exceeds the fixed costs that arise with the business activity of the company. I.e. subtracting both of the portfolio utility U^*, the average NPV of indirect fixed costs per capita and the weighted sum of direct fixed costs per capita of the segments of set S, yields the condition

(Ap2.2) $$U^* - \sum_{i \in S} w_i \cdot NPV\left(\hat{F}_i\right) - NPV(I\hat{C}) \geq 0.$$

If the left-hand side of inequality (Ap2.2) is negative, the customer portfolio does not create utility for the company, since the company cannot cover all its costs at the given number N of customers in the portfolio. In this case, the enlargement of the number of customers should be considered for example.

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[7] Even if the number of customers N depends on the number of customer segments n in the portfolio, i.e. $N = N(n)$, the number of customers in each customer segment will change, because of the re-optimization of the portfolio shares w_j in the next iteration. Therefore, the fixed costs per capita in the respective segment will change as well.

[8] However, the weighted sum of the per capita fixed costs of the other segments in set S_i remains constant, as was discussed in the footnote 3 and is therefore not relevant for the portfolio decision.

Step 3: Results of the "Subtract"-Approach

If all fixed costs are covered by the utility of the portfolio, the results of the "subtract"-approach are the following:

- Set of the segments in the resulting portfolio
- Portfolio weights of the segments in the portfolio
- Utility minus indirect and direct fixed costs per capita of the resulting portfolio

APPENDIX 3: Detailed Description of the "Add"-Approach

Step 1: Decision about Taking Further Segments into the Customer Portfolio

The starting set S of segments in the portfolio is the set of segments being subject to minimum constraints. All remaining segments are now, one at a time, taken into the portfolio. Denote S_i as the portfolio including segment i and U_i the respective portfolio utility, which is the result of the re-optimization of the portfolio shares w_i without consideration of the segments' fixed costs. A customer segment more in the portfolio leads in general to a higher portfolio utility, because of the effects of risk diversification as was noted before. Determine the delta ΔU_i between the new portfolio utility U_i and the portfolio utility of the previous iteration, which is referred to as U^* for all new portfolios. However, another consequence of a larger number of segments in the portfolio is usually a smaller number of customers in the segments j, with $j \neq i$, that were part of the portfolio before the inclusion of segment i. Therefore, their per capita fixed costs of equation (3.5) increase in general with the inclusion of segment i.[9] If ΔU_i is larger than the weighted NPV of the fixed costs per capita of the just included segment i, i.e. if

(Ap3.1) $$\Delta U_i > w_i \cdot NPV(\hat{F}_i) \overset{(3.5)}{=} \frac{1}{N}\sum_{t=0}^{T}\frac{F_{i,t}}{\left(1+r_f\right)^t},$$

the segment creates utility. If no such i exists, the algorithm goes to step 2.

Out of those segments creating utility, pick that segment i with maximal $\Delta U_i - w_i \cdot NPV(\hat{F}_i)$. The set S_i of segments in this portfolio is the starting point for the next iteration and therefore becomes the new set S and U^* takes the value of U_i.

Again, take all of the remaining segments one at a time into this portfolio and repeat the just described procedure until the incremental increase of portfolio utility, caused by the inclusion of a further segment, yields no more i satisfying inequality (Ap3.1). Then, the algorithm goes to step 2.

Step 2: Checking whether Fixed Costs are covered

As a result of step 1, no more customer segment can be included in the portfolio that creates utility. However, the customer portfolio of step 1 should be realized, and the algorithm should go to step 3, only if the portfolio utility exceeds all fixed costs that arise with the business activity of the company. I.e. subtracting both of the portfolio utility U^*, the average NPV of the indirect fixed costs per capita and the weighted sum of direct fixed costs per capita of the segments in the portfolio, yields again

(Ap3.2) $$U^* - \sum_{i \in S} w_i \cdot NPV\left(\hat{F}_i\right) - NPV(I\hat{C}) \geq 0.$$

If the left-hand side of inequality (Ap3.2) is negative, the customer portfolio does not create utility for the company, since the company cannot cover all its costs at the given number N of customers in the portfolio.

[9] However, analogous to the footnote 8, the weighted sum of the per capita fixed costs of the segments that were already in the portfolio remains constant and is therefore not relevant for the portfolio decision.

Step 3: Results of the "Add"-Approach

If all fixed costs are covered by the utility of the portfolio, the "add"-approach produces similar results as the "subtract"-approach:

- Set of the segments in the resulting portfolio
- Portfolio weights of the segments in the portfolio
- Utility minus indirect and direct fixed costs per capita of the resulting portfolio